

A review of the endemic chameleon genus *Brookesia* from Madagascar, and the rationale for its listing on CITES Appendix II

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Abstract The chameleon genus *Brookesia*, with 26 species, is endemic to Madagascar. The main threats to *Brookesia* are habitat destruction and collection for trade. At the CITES Conference of Parties 12, held in Santiago, Chile in 2002, all but one *Brookesia* species were added to Appendix II, under which trade is controlled in order to avoid utilization being incompatible with species' survival. The Vulnerable *B. perarmata* was added to Appendix I, under which trade is permitted only in exceptional circumstances. Summary information for *Brookesia* is presented here, reviewing taxonomy, habitat preferences, available population estimates, relevant legislation, major threats, and trade levels. *Brookesia* live on or close to the ground, with roost sites mostly <1 m above ground. Density estimates are available for only a few

species, with a mean density estimate for four species across sites and seasons of 16 individuals ha⁻¹. A number of species have distinct altitudinal ranges, and a preference for primary forest. Continued deforestation will therefore potentially lead to extirpations. Research on population sizes and seasonal trends of *Brookesia* is required, without which, combined with data on the impacts of harvesting, the establishment of sustainable trade will not be possible. The apparent reduction and possible cessation of trade in *B. perarmata* following its listing on CITES indicates that the Convention can succeed in managing global trade in a threatened species.

Keywords *Brookesia*, chameleon, CITES, Madagascar, wildlife trade.

Introduction

Trade in wildlife is monitored through the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). At the CITES Conference of Parties (CoP) 12, held in Santiago, Chile in 2002 chameleons of the genus *Brookesia* were added to Appendix II, under which trade is controlled to avoid utilization compromising species' survival. The Vulnerable *B. perarmata* (IUCN, 2004) was added to Appendix I, under which trade is permitted only in exceptional circumstances. Chameleon species other than those in the genera *Rhampholeon* and *Brookesia* have been included on Appendix II since the early 1970s (Rosser *et al.*, 2001).

Conservation concerns for chameleons arise primarily from habitat destruction and secondarily from trade (JNCC, 1993; Brady & Griffiths, 1999). Using data from the CITES Trade Database (UNEP-WCMC, 2005) a

review of the dynamics of the global trade in chameleons has been conducted for species in the genera *Furcifer*, *Bradypodion*, *Calumma* and *Chamaeleo* (Carpenter *et al.*, 2004). Because *Brookesia* was not listed on a CITES Appendix trade was not officially monitored, although some trade data were provided voluntarily by member states.

A summary of the taxonomy, ecology, distribution and available trade data for *Brookesia* was provided for Party members at CoP 12, but the summary was not available to all CoP 12 participants or to interested conservationists and researchers. This summary information is presented here, reviewing taxonomy, habitat preferences, available population estimates, relevant legislation, major threats, and trade levels.

Taxonomy, ecology & distribution

The family Chamaeleonidae contains two subfamilies, *Brookesiinae* and *Chamaeleoninae*, and six genera (Uetz, 2004). Within the *Brookesiinae* there are two genera, *Brookesia* and *Rhampholeon*. The 26 species of *Brookesia* (Table 1) are endemic to Madagascar (Uetz, 2004). A summary of the biology and ecology of the species is presented in Table 2. Raxworthy & Nussbaum (1995), Glaw *et al.* (1999) and Glaw & Vences (1994) provide taxonomic information.

Confusion exists concerning the relationship *Brookesia* has with its environment, leading to statements that

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Table 1 Summary of *Brookesia* taxonomy and distribution, extracted from [http://srs.embl-heidelberg.de:8000/srs5bin/cgi-bin/wgetz?\[REPTILIA-Species:Brookesia*\]](http://srs.embl-heidelberg.de:8000/srs5bin/cgi-bin/wgetz?[REPTILIA-Species:Brookesia*]) [accessed 10 August 2005].

Species	Synonyms	Distribution	Comments*
<i>B. ambreensis</i>		Montagne de Ambre National Park	Holotype UMMZ 203635
<i>B. antakarana</i>		Montagne de Ambre National Park	Holotype UMMZ 200071
<i>B. bekolosy</i>		Manongarivo Special Reserve, Bekolosy	Holotype UMMZ 200078
<i>B. betschi</i>		Medium altitude (1,300 m) forest at Marojezy	
<i>B. bonsi</i>		Tsingy de Namoroka, Soalala	Holotype MHNP 1978.1992.
<i>B. brygooi</i>		SW Madagascar	Holotype MHNP 8219
<i>B. decaryi</i>		Ankarafantsika Massif, NW Madagascar	Syntypes MHNP 1938. 158–162
<i>B. dentata</i>	<i>B. ramanantsoai</i>	NW Madagascar	Holotype MHNP 99.322; <i>B. dentata</i> and <i>B. ramanantsoai</i> synonymized by Raxworthy & Nussbaum (1995)
<i>B. ebenau</i>	<i>Chamaeleo ebenau</i> , <i>B. legendrei</i>	Nosy Bé	Holotype SMF 16515
<i>B. exarmata</i>		Tsingy de Bemaraha, W Madagascar	
<i>B. griveaudi</i>		NE Madagascar	
<i>B. karchei</i>		Massif du Marojezy	
<i>B. lambertoni</i>			
<i>B. lineata</i>		Manongarivo Special Reserve, Bekolosy	Holotype UMMZ 200073
<i>B. lolontany</i>		Tsaratana Mt.	Holotype UMMZ 203629
<i>B. minima</i>		NW Madagascar and Nosy Bé	<i>B. minima</i> , <i>B. tuberculata</i> and <i>B. peyrierasi</i> synonymized by Raxworthy & Nussbaum (1995), but reversed by Glaw <i>et al.</i> (1999)
<i>B. nasus</i>	<i>B. nasus</i> , <i>B. betsileana</i> , <i>Evoluticauda nasus</i> Subspecies: <i>B. nasus pauliani</i> , <i>B. nasus nasus</i>	Ekongo, Manjarivolo, l'Andringitra, SE Madagascar	
<i>B. perarmata</i>	<i>Leandria perarmata</i>	W Madagascar	Holotype MNHP 1935–145
<i>B. peyrierasi</i>	<i>B. minima</i>	NE Madagascar	Holotype MHNP 1968.190; <i>B. minima</i> , <i>B. tuberculata</i> , and <i>B. peyrierasi</i> synonymized by Raxworthy & Nussbaum (1995), but reversed by Glaw <i>et al.</i> (1999)
<i>B. stumpffi</i>		Nosy Bé and NW Madagascar	Lectotype SMF 16475
<i>B. superciliaris</i>	<i>Chamaeleo superciliaris</i> , <i>C. brookesianus</i> , <i>C. brookesia</i> , <i>C. brookesii</i> , <i>C. brookesiana</i>	E Madagascar	
<i>B. therezieni</i>		E Madagascar	
<i>B. thieli</i>	<i>B. antoetrae</i>	E & N Madagascar	<i>B. antoetrae</i> synonymized with <i>B. thieli</i> (Raxworthy & Nussbaum, 1995)
<i>B. tuberculata</i>	<i>B. minima</i>	N Madagascar	Holotype MHNP 93.183.; <i>B. minima</i> , <i>B. tuberculata</i> & <i>B. peyrierasi</i> synonymized (Raxworthy & Nussbaum, 1995), but later reversed (Glaw <i>et al.</i> , 1999)
<i>B. vadoni</i>		Near Masoala	
<i>B. valerieae</i>		Manongarivo Special Reserve	

*Types are only provided for those that have been traced. MHNP, Muséum National d'Histoire Naturelle, Paris; UMMZ, University of Michigan, Museum of Zoology; SMF, Senckenberg Museum, Frankfurt.

species are incapable of adjusting to environmental change (Necas, 1999) or, conversely, are highly adaptable (LeBerre, 1995). *Brookesia* are known, however, to be restricted to discrete altitudinal zones within a range

of 0–2,050 m altitude, to occur mostly in primary forest, and to occupy distinct roost sites within the chameleon assemblage (Raxworthy & Nussbaum, 1995; Carpenter, 2003). Roost sites are considered good indicators of the

Table 2 A summary of the distribution, ecology and biology of those *Brookesia* spp. for which information is readily available.

Species	
<i>B. ambreensis</i>	Possibly endemic to Montagne d'Ambre, in primary rainforest over 650–1150 m. Males (snout-vent length, SVL, 44–52 mm) smaller than females (SVL 52–55 mm) although sample size was small (Raxworthy & Nussbaum, 1995).
<i>B. antakarana</i>	On Montagne d'Ambre & also considered endemic to northern Antakarana. Found in rainforest at 650–1200 m, it roosts between ground level & 1.5 m (Raxworthy & Nussbaum, 1995).
<i>B. bekolosy</i>	Only a single male (34 mm SVL) has been recorded, collected from primary forest at 1,200 m on the Bekolosy plateau at Manongarivo, with a roost site 1 m above ground (Raxworthy & Nussbaum, 1995).
<i>B. brygooi</i>	At Analavelona, Sakaraha, Kasijy & near Toliara, SW Madagascar. Brygoo is cited (in Raxworthy & Nussbaum, 1995) as recording the species in Reserve Naturelle Integrale No. 11, Bemaraha & Antsalova. Maximum SVL of males 52 mm (tail 38 mm) & females 48 mm (tail 33 mm). Found in the arid SW & W, it is one of the few <i>Brookesia</i> adapted to arid environments & is probably restricted to native deciduous forests in these regions (Raxworthy & Nussbaum, 1995).
<i>B. decaryi</i>	Only a small range, located at Ankarafantsika, NW Madagascar, where there are significant seasonal changes in climate & vegetation, & abundance is apparently linked to these fluctuations (Carpenter, 2003).
<i>B. ebenau</i>	Described from the island of Nosy Bé in 1893. Inhabits humid & secondary growth forest & considered more arboreal than its congeners. Often labelled <i>B. legendrei</i> , which was considered a junior synonym for <i>B. ebenau</i> , in pictures of the species.
<i>B. exarmata</i>	In Tsingy de Bemaraha, W Madagascar. Occurs sympatrically with <i>B. brygooi</i> & <i>B. perarmata</i> . Described in 1996.
<i>B. lineata</i>	Unusual for <i>Brookesia</i> , with flanks marked by bold, dark brown, longitudinal lines. Only one individual recorded, from Bekolosy, Manongarivo Special Reserve at 1,200 m, with SVL of 45 mm. Not known from any other localities, & was recorded in primary forest roosting 1 m above ground (Raxworthy & Nussbaum, 1995).
<i>B. lolontany</i>	In the Tsaratanana Mountains, N Madagascar. Two females were collected at 2,050 & 1,600 m from primary forest, one dominated with bamboo, roosting at 0.7 & 0.05 m above ground, with SVLs of 32 mm (tail 18 mm) & 28 mm (tail 15 mm; Raxworthy & Nussbaum, 1995).
<i>B. minima</i>	Forms a species group with <i>B. dentate</i> & <i>B. tuberculata</i> . Considered the smallest of all Chamaeleonidae, it inhabits the floor of rainforest on the island of Nosy Bé. Also recorded at Anjajavy, in 2000–2001, on the coast of NW Madagascar (Carpenter, 2003). Males smaller & more slender than females.
<i>B. perarmata</i>	In the Antsingy region of Menabe Province, W Madagascar. Inhabits bushes & the forest floor, & attains a total length of 110 mm. Distinguished by bilateral rows of thorny spines along the dorsal surface.
<i>B. thieli</i>	In E central Madagascar & considered locally abundant, inhabiting the rainforest floor.
<i>B. stumpffi</i>	On Nosy Bé in leaf litter & rotting tree trunks on the rainforest floor. Carpenter (2003) also recorded the species in dry forests & disturbed sites along the coast of NW Madagascar. One of the larger <i>Brookesia</i> , with a total length of up to 100 mm.
<i>B. superciliaris</i>	Inhabits the rainforest floor in coastal regions of E Madagascar & the island of Nosy Boraha. One of the larger <i>Brookesia</i> , with a total length of up to 100 mm.

foraging locations of chameleons (Akani *et al.*, 2001). *Brookesia* are generally cited as being terrestrial (Glaw & Vences, 1994), and roost sites are consistently lower than in other chameleon genera (Carpenter, 2003). *B. stumpffi* has the highest recorded roost sites (mean height 0.43 m \pm 0.34 SD), but still > 2 m lower than co-occurring *Fucifer angeli*. *Brookesia decaryi* has the lowest recorded roost sites, (mean height 0.17 m \pm 0.08 SD; Carpenter, 2003).

Studies of *Brookesia* have mostly focused on site-specific inventories (Raxworthy, 1988; Raxworthy & Nussbaum, 1995), with little known about the abundance of individual species. Available abundance and density estimates have been used to indicate preferred habitats but there is a lack of agreement between studies, even for the same species. For example, *B. nasus* has been recorded in higher numbers than conspecifics in both slightly disturbed habitats (Jenkins *et al.*, 1999) and undisturbed riparian forest (Jenkins *et al.*, 2003). Anthropogenic factors can affect *Brookesia* abundance. At Andranomay, for example, abundance was higher in undisturbed sites (*B. thieli*, 58 ha⁻¹; *B. minima*, 7 ha⁻¹)

compared to burnt sites (*B. thieli*, 20 ha⁻¹; *B. minima*, 0.0 ha⁻¹; Rabearivony, 1999). *Brookesia* abundance also fluctuates between seasons. At Ranomafana National Park, for example, density estimates were greater in the summer (*B. superciliaris* 39 ha⁻¹, *B. nasus* 41 ha⁻¹, *B. thieli* < 0.1 ha⁻¹) compared to the winter (*B. superciliaris* 14 ha⁻¹, *B. nasus* 6 ha⁻¹, *B. thieli* < 0.1 ha⁻¹) (Rabearivony, 1999).

No studies are currently investigating population sizes or trends in any species of *Brookesia*. Attempts to record abundance have encountered persistent problems with either too little or no data (Ramilison & Rabibisoa, 1998; Rabearivony, 1999), often due to a combination of factors such as censusing difficulties, availability of suitable habitat and the low densities of some species. Rabearivony (1999) combined data for several species, generating density estimates of the genus that varied between zero and 74 individuals ha⁻¹, and a mean density estimate for four species across sites and seasons of only 16 individuals ha⁻¹.

Threats, legislation and trade

The main threats to *Brookesia* are habitat destruction and trade. Habitat destruction is a major threat to all flora and fauna on Madagascar, and in contrast to the application of conservation efforts, greater areas of seasonal forest have been lost in recent years compared to rainforest (Whitmore, 2000). In western Madagascar only 1% of natural relict forest, in this deciduous forest region, is under any form of protection, and a total area of only c. 11,000 km² is under protection in all of Madagascar (ANGAP, 2001).

Harvesting of *Brookesia* for the pet trade has been recorded within protected areas (Ramilison & Rabibisoa, 1998) although harvesting is not the main threat to *B. nasus* in Ranomafana National Park (Jenkins *et al.*, 1999). Limited information has been recorded on the economic or network structures of trade (Ramilison & Rabibisoa, 1998; Brady & Griffiths, 1999; Rabearivony, 1999), although details of both network and economic structures has been recorded for other genera (Carpenter, 2003; Carpenter *et al.*, 2005). This showed that those involved in the 'true' chameleon trade were also trading in *Brookesia*. A survey of pet shops advertising *Brookesia* species for sale on the internet in 1999 recorded nine species (Rabearivony, 1999), whereas a similar survey in 2004 found only two websites (one advertising *B. perarmata* and one advertising *B. superciliaris*, for \$49.99 each).

In Madagascar the Ministère des Eaux et Forêts stipulates that the collection of *B. perarmata* is not permitted. This notification is provided on the reverse of collection permits issued by the Ministry to exporters. Under EC regulation No.338/97, seven species (*B. decaryi*, *B. ebenauai*, *B. minima*, *B. perarmata*, *B. stumpffi*, *B. superciliaris* and *B. thieli*) are listed under the European classification of 'D'. The annex 'D' monitoring system is intended as an early detection of possible conservation concern in species not listed on CITES (JNCC, 2001). In January 2004, at the 28th meeting of the EU Scientific Review Group in Brussels, under Articles 4.1(a)(i) and 4.2(a) of Regulation 338/97, a decision to refuse subsequent import applications for wild taken specimens of *B. decaryi* and *B. thieli* from Madagascar was implemented (UK CITES, 2004).

The government of Madagascar dictates that exporters submit applications prior to the export of any wildlife consignment to the Ministère des Eaux et Forêts and the Ministère de l'Élevage. These applications include CITES permits, Certificat sanitaire pour l'exportation des animaux vivants, orders for non-CITES species and invoice documentation, which are filed with both ministries. I extracted data from these documents on the species and number of individuals reported as exported in 2001, the only year for which records were available when I searched in 2002. Data were also extracted from the US Law Enforcement Management Information System

(LEMIS), providing a data set to review reported imports to the USA between 1996 and 2001, and from UNEP-WCMC (2005), compiled on 5 July 2004.

Between 1996 and 2001 the LEMIS data reported a total of c. 4,000 individual *Brookesia* imported to the USA, whereas in 2001 only, Madagascar data reported a total of c. 3,000 individuals exported. Between 1997 and 2003 CITES data reported a total of c. 2,500 *Brookesia*, of which Germany accounted for 46% of imports, followed by the USA (16%) and UK (15%). However, there are potential problems with CITES data, with 6 month reporting delays and export data often extracted from CITES permits rather than actual trade (Jenkins & Broad, 1994; Harwood, 1999; Carpenter, 2003). LEMIS data show *Brookesia* imports to the USA decreased by an order of magnitude in 1998–1999, but increased greatly again in 2000 (Fig. 1). The LEMIS and CITES data report similar values for 1997 and 1999, indicating that either the USA imported nearly all *Brookesia* or it was the only country to report trade. LEMIS data fluctuates greatly between years compared with CITES data. Madagascar export data for 2001 show trade nearly four times higher than the corresponding LEMIS data and nearly six times higher than the corresponding CITES data (Fig. 1).

The total number of species recorded in data sets differs. The LEMIS and CITES data record eight species and the Malagasy data 12 species (Table 3). Malagasy data record four species that are not in the LEMIS data (*B. felix*, *B. thieli*, *B. vadoni* and *B. legendrei*), and four that are not in the CITES data (*B. felix*, *B. brygooi*, *B. therezieni* and *B. legendrei*). However, names used by some exporters, such as *B. legendrei* as a synonym for *B. ebenauai* (Table 1), result in mislabelling of consignments. Moreover, importing states appear to record consignment contents only in taxonomic classifications they agree with. Therefore, only *B. ebenauai* has been recorded in CITES or LEMIS data, as *B. legendrei* is not a recognized name. Similarly, because *B. ramanantsoai* is a synonym for *B. dentata*, a similar situation appears to have occurred, with importing states only recording *B. dentata*. Of the 26 species, 10 (38%) are reported to be exported from Madagascar. One species, *B. felix*, is recorded in trade data but is not included in Table 1; the legitimacy of *B. felix* is in debate (F. Glaw, pers. comm.).

Between 1996 and 2001 LEMIS data were recorded every year for *B. superciliaris* and unidentified *Brookesia* species. Known species were traded on average for 3 years in this period, with *B. ramanantsoai* and *B. therezieni* recorded in only 1 year. The species with the highest total number of individuals imported to the USA during this period was *B. perarmata* (2,215) followed by *B. superciliaris* (797). These two species account for nearly 75% of the total number of known individuals (4,055) imported to the USA. The same two species account for c. 40% of the export figure from Madagascar in 2001, and when

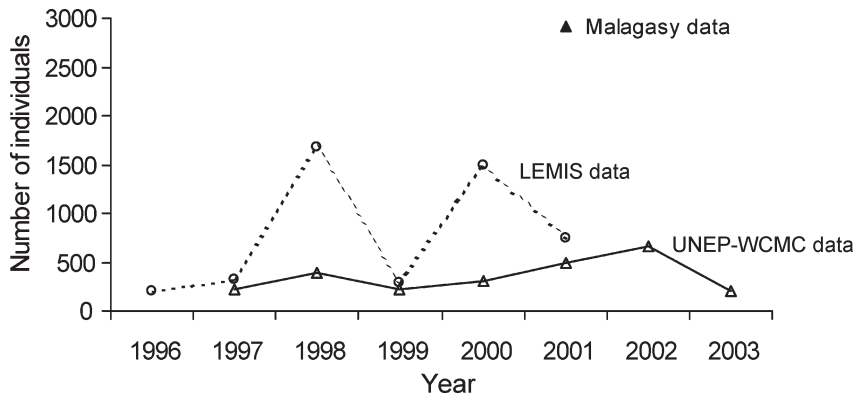


Fig. 1 The total number of individuals of *Brookesia* recorded as imported per year to the USA during 1996–2001 (from the US Law Enforcement Management Information System), exported from Madagascar in 2001 (from the Ministère des Eaux et Forêts), and exported from Madagascar during 1997–2003 (from UNEP-WCMC, 2005) (see text for details).

combined with *B. decaryi* and *B. thieli* account for >71% of the total export figure. Between 1997 and 2003, four species (*B. superciliaris*, 35%; *B. thieli*, 25%; *B. perarmata*, 15%; *B. decaryi*, 10%) accounted for 85% of the CITES trade figure. CITES data sets are dynamic (see Carpenter, 2003, for details), but data recorded for *B. perarmata* in 2002 (24) and 2003 (3) are the lowest and third lowest on record. This suggests that trade in this species is ceasing since its addition to CITES Appendix I in 2002.

The Malagasy government officially assigns minimum export values to *Brookesia* of USD 15 each, except *B. perarmata* and *B. vadoni*, which are assigned USD 64 each. Using these minimum export values the revenues generated using Madagascar export data total c. USD 75,000 for 2001 only. The LEMIS data total USD 179,260 for the

period between 1996 and 2001 and CITES data total USD 56,170. The trade chain consists of three links, village collector, intermediary and exporter, with collectors receiving only 1.05% and intermediaries only 1.22% of the total income generated by the trade (Carpenter, 2003).

Discussion

It is likely that new species of *Brookesia* will be described in the near future (Glaw & Vences, 2000), compounding current taxonomic problems in the genus, and potentially resulting in increased mislabelling, either accidental or intentional, on future consignments. Efforts should be made to assist the management authority of Madagascar to keep up to date with any future taxonomic changes and thus ensure species in consignments are correctly reported (Carpenter, 2002). CITES is currently in the process of conducting the first country-based review of significant trade, with Madagascar the focus country (Earth Negotiations Bulletin, 2004).

Well established management of trade should ensure that no collection is undertaken from protected areas. It would also permit an investigation of the impact of harvesting on abundance and demography; this is currently also required for 'true' chameleons. Current management practices in Madagascar have been shown to be detrimental to both conservation and poverty alleviation (Carpenter 2003; Carpenter *et al.*, 2005). Management should implement economic and trade structures to allow local people to benefit from the trade whilst facilitating an income shift away from unsustainable forest practices (Carpenter *et al.*, 2005).

The available information indicates that *Brookesia* are located on or close to the ground, with roost sites often <1 m above ground, and many species have distinct altitudinal ranges and a preference for primary forest. Continued deforestation will therefore potentially lead to extirpations. Research is required on population sizes and seasonal trends of *Brookesia*, without which, combined with data on the impacts of harvesting, the establishment of sustainable trade will not be possible. This should be viewed as urgent for species that are traded.

Table 3 Total number of individuals of *Brookesia* species recorded as imported to the USA during 1996–2001 (from the US Law Enforcement Management Information System), exported from Madagascar in 2001 (from the Ministère des Eaux et Forêts), and exported from Madagascar during 1997–2003 (from UNEP-WCMC, 2005) (see text for details). *B. felix*, *B. legendrei* and *B. ramanantsolai* are not in Table 1; see text for explanation.

Species	Imported to USA, 1996–2001	Exported from Madagascar, 2001	Exported from Madagascar, 1997–2003
<i>B. brygooi</i>		60	
<i>B. decaryi</i>	214	457	262
<i>B. ebenauui</i>	378	162	21
<i>B. felix</i> (status uncertain)		20	
<i>B. legendrei</i> (= <i>B. ebenauui</i>)		50	
<i>B. minima</i>	342	162	180
<i>B. perarmata</i>	2215	573	375
<i>B. ramanantsolai</i> (= <i>B. dentata</i>)	20		
<i>B. stumpffi</i>	79	240	142
<i>B. superciliaris</i>	797	522	872
<i>B. therezieni</i>	10	50	
<i>B. thieli</i>		411	625
<i>B. vadoni</i>		51	10
<i>Brookesia</i> spp.	660		
Total	4,715	2,758	2,487

The addition of *Brookesia* to CITES Appendix II is precautionary. With limited information available on the genus, some of it contradictory, listing on CITES Appendix II was the only practical option. Trade in the genus was increasing both in numbers and diversity, distributions extremely local, and densities low in some species. The apparent reduction and possible cessation of trade in *B. perarmata* indicates that CITES can succeed in managing global trade in a threatened species.

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