Conservation status of the Endangered Nubian dragon tree *Dracaena ombet* in Gebel Elba National Park, Egypt

M. Kamel, U. M. Ghazaly and M. W. Callmander

Abstract The Nubian dragon tree *Dracaena ombet*, which is categorized as Endangered on the IUCN Red List, is found on the highest slopes of Gebel Elba National Park in Egypt, with scattered populations in Sudan, Djibouti, Ethiopia and Somalia. The Gebel Elba population is threatened by drought. Surveys were conducted in the Park to assess the condition and document the distribution of the species to prepare a baseline for conservation efforts. Eight sites were surveyed during 2007–2009: trees were tagged and their locations were recorded using a global positioning system, and tree density, diameter at breast height and population status were estimated. Of 353 trees recorded only 46% (161 individuals) were alive and only 27% (96 individuals) were in a healthy condition. Only 1% (2 individuals) were young trees, indicating a low regeneration level. Field-based observations suggest that 80% of the *D. ombet* population in Gebel Elba may soon be extinct. A conservation action plan is needed for this flagship species in Egypt and throughout its range.

Keywords Climate change, conservation, *Dracaena ombet*, Egypt, Endangered species, Gebel Elba, IUCN Red List, Nubian dragon tree

Introduction

Plants play a key role in maintaining healthy ecosystems and they provide essential habitat for animal species (CBD, 2011). They also provide vital resources, such as food, timber and fibres, and many plants have great cultural importance (CBD, 2011). Plant conservation is increasingly important in the face of the many threats to plant diversity, including climate change, land-use change, over-exploitation, pollution and invasive alien species (CBD, 2011).

M. Kamel (Corresponding author) Botany Department, Faculty of Sciences, South Valley University, 83523 Qena, Egypt
E-mail mohamedkamelahmed@yahoo.com

U. M. Ghazaly Gebel Elba Protected Area, Nature Conservation Sector, Gebel Elba, Egypt

M. W. Callmander Missouri Botanical Garden, St. Louis, Missouri, USA, and Conservatoire et Jardin botaniques de la Ville de Genève, Chambésy, Switzerland

Received 4 January 2013. Revision requested 22 May 2013.
Accepted 1 October 2013. First published online 1 July 2014.

The genus *Dracaena* L. comprises c. 100 species and ranges from Macaronesia to Australia, with one species in the Neotropics (Bos, 1998). Taxonomic revisions are being carried out throughout its range and threatened narrow endemics of the genus have been described from Africa (Mwachala et al., 2007; Mwachala & Cheek, 2012; Mwachala & Fisher, 2013) and South-east Asia (Wilkin et al., 2012), with c. 46 species described for Africa (Mwachala & Fisher, 2013).

Among *Dracaena*, the dragon tree group, which has a unique and distinctive appearance (Plate 1), comprises 10 arborescent species (Wilkin et al., 2012), all growing in seasonally arid climates with annual rainfall of 200–500 mm and mean temperatures of 18–20 °C (Marrero et al., 1998; Adolt & Pavlis, 2004). These species exhibit a biogeographical disjunction, regarded by Adolt & Pavlis (2004) as 'a relic representation of the Mio-Pliocene Laurasian subtropical flora'. Four species are known in South-east Asia (*Dracaena cambodiana* Pierre ex Gagnep., possibly conspecific with *D. cochinchinensis* (Lour.) S. C. Chen, *D. jayiana* Wilkin & Suksathan, and *D. yuccifolia* Ridl.), two in Macaronesia (*D. draco* L. and *D. tamaranae* Marrero Rodr. et al.), two in Africa (*D. ellenbeckiana* Engl. and *D. ombet* Heuglin ex Kotschy & Peyr., incl. *D. schizantha* Baker; Thulin, 1995), one in the Arabian Peninsula (*D. serrulata* Baker, sometimes considered a conspecific of *D. ombet*), and one endemic to Socotra (*D. cinnabari* Balf. f.).

The Nubian dragon tree *Dracaena ombet*, a flagship species (Vincent, 2008) of the Afromontane areas of north-east Africa, is found in bushland and woodland on mountain slopes facing the Red Sea, generally at 1,000–1,800 m (Thulin, 1995). The main population occurs in the Gebel Elba Mountains in south-east Egypt (Ghazali et al., 2008) and additional populations are found on Mount Erkowit in Sudan, on the escarpments of the Eritrean Mountains, and in Somaliland, Somalia and Ethiopia (Kassas, 1956; Friis, 1992; Thulin, 1995; Bos, 1997), with a few scattered populations in the Horn of Africa (Audru et al., 1987; Friis & Lawesson, 1993; Magin, 1999).

D. ombet is categorized as Endangered on the IUCN Red List (WCMC, 1998), based on an assessment made using a now outdated set of criteria (v. 2.3; IUCN, 1994). A survey of the Gebel Shindeeb population in the southern part of Gebel Elba National Park conducted by El Azzouni (2003) revealed that it comprised only mature plants,

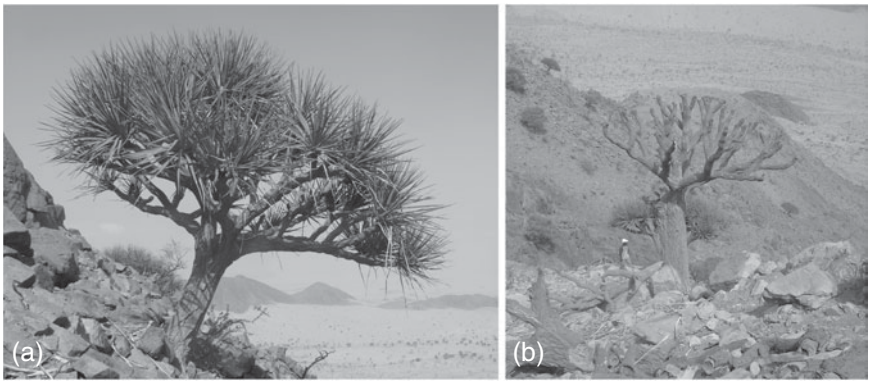

PLATE 1 Nubian dragon tree *Dracaena ombet* in vivo in Gebel Elba National Park, Egypt (Fig. 1). (a) Healthy mature tree. (b) Dried tree as a result of drought.

many of which appeared unhealthy as a result of drought conditions, attack by a parasitic pest, and/or disease. *D. ombet* is extirpated in Erowit, in northern Sudan, one of the few areas where the species had survived in that country (El Azzouni, 2003). These observations point to a rapid decline of the Nubian dragon tree in at least part of its range. In south-eastern Egypt the species generally occurs in remote, high-elevation areas that are difficult to access, and no reliable information is available regarding its ecology and conservation status in this part of its range.

A survey and monitoring project was launched in 2007 to support a conservation action plan for the Egyptian population of *D. ombet* (Ghazali et al., 2008). A survey of its distribution in Gebel Elba National Park was undertaken during October 2007–March 2009. Comprehensive geographical information system-based mapping and eco-geographical surveys were used to identify areas of current distribution and to assess the status and health of the Gebel Elba population. This provides the first accurate baseline for developing a conservation strategy to protect *D. ombet* in an effort to prevent its extinction within the Park. Furthermore, the survey generated the data necessary for a preliminary IUCN risk assessment at the regional level, using IUCN Criteria v. 3.1 (IUCN, 2012). An updated Red List assessment is also provided for *D. ombet* throughout its range.

Study area

Gebel Elba National Park (c. 35,600 km^2) is located in south-eastern Egypt (Fig. 1), immediately north of the border with Sudan. The Park includes a cluster of coastal mountains overlooking the Red Sea, the most prominent peaks being Gebel Kam Erba (1,374 m), Gebel Shellal (1,409 m), Gebel Elba (1,435 m), Gebel Shendodai (1,526 m) and Gebel Shendeib (1,911 m). Although not the highest peak, Gebel Elba has the highest levels of precipitation because it is closest to the sea and faces the north-east winds. The Gebel Elba region is recognized as a biodiversity hotspot, located among the northern outliers of the Horn of Africa hotspot (Conservation International, 2013). Many Afrotropical elements reach their northern limits at Gebel Elba, contributing to a level of biological diversity that is unmatched anywhere else in Egypt (Ghazali et al., 2008).

In the southern part of the Egyptian desert the mean monthly temperature is 20.9 °C in January and 31.9 °C in August (range 16.8–37.1 °C; NCDC, 2013). Mean annual rainfall in the region is $<$ 50 mm but in Gebel Elba the prevailing south-east winds bring mist and clouds to the mountain slopes (Abu Al-Izz, 1971), where orographic precipitation produces up to 400 mm of rainfall per year. These localized conditions have facilitated the establishment of a rich and diverse flora (350 species), including several tree species that grow at higher elevations (Ghabbour, 1997).

Methods

The distribution of *D. ombet* in Gebel Elba National Park was recorded through field surveys conducted with the participation of the local community (Ghazali et al., 2008). Stands of the tree were found on three mountain massifs within the Park: Gebal Kam Erba, Gebel Elba and Gebel Shendeib (Fig. 1). Only populations on the most northern massif, Gebel Elba, were surveyed in detail because of the proximity of the area to the Sudanese border, which is unsafe to visit. The following parameters were recorded: number of trees, composition of associated plant communities, and level of grazing along the mountain's elevational gradient. The precise location of trees was recorded using a global positioning system (GPS) unit. Diameter at breast height (DBH) and total tree height were recorded for each individual, and each tree was categorized as healthy ($>$ 70% of the tree parts were living), moderately healthy (35–70%), unhealthy or weak (1–35%) or dead (0%). All living trees were marked with an aluminium tag bearing a unique number, for further monitoring. The age structure of the Gebel Elba Mountain population was recorded along with phenological status. Branching attributes, including branch height and number, were also recorded. To evaluate regeneration status we recorded the population size at each of four stages of maturity: seedlings, sprout shoots,

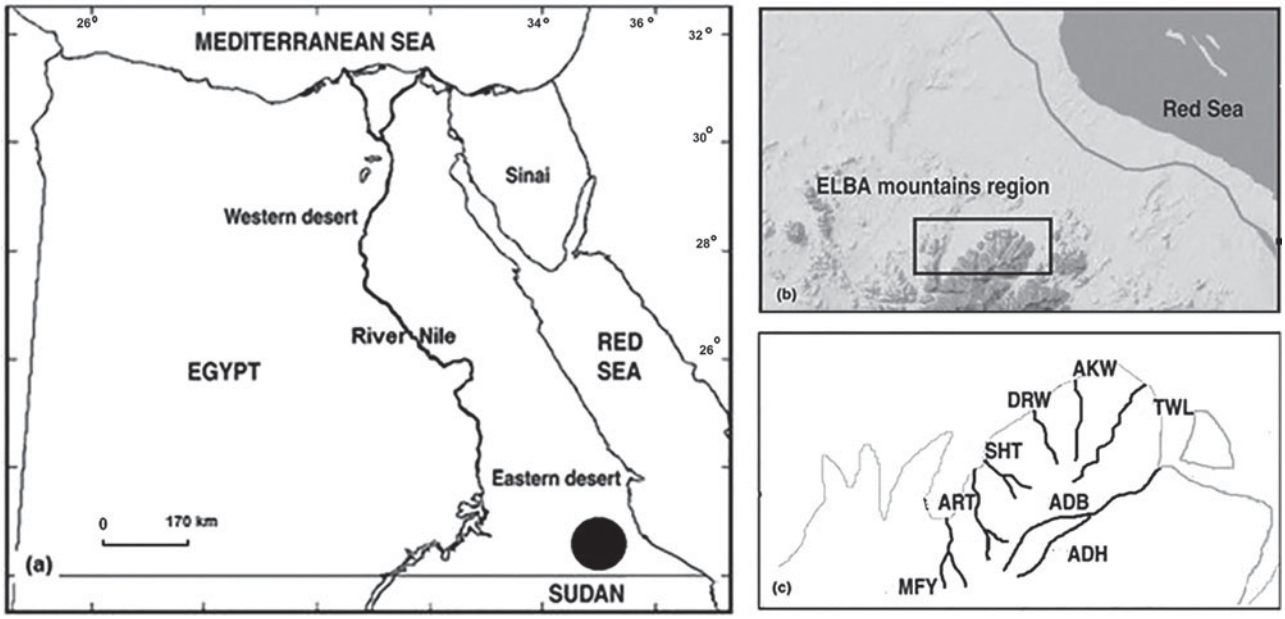

FIG. 1 The study area in Gebel Elba National Park, Egypt. The filled circle on (a) shows the location of the Gebel Elba region. The rectangle on (b) shows the location of the eight wadi surveyed (c). ADH, Aedieb Hills; ADB, Aedieb; AKW, Akaw; ART, Aretri; DRW, Darawina; MFY, Marafay; SHT, Shtet; TWL, Tawella.

saplings and mature trees. Seed dispersal and seedling survival in relation to distance from the mother plant were estimated by counting the number of seedlings and saplings and recording their distance from the presumed mother plant.

Data were analysed and distribution maps were generated using *ArcView v.3.2* (ESRI, Redlands, USA), facilitating analysis of the spatial distribution of trees and determination of the areas of highest species density (population hotspots). For the preliminary assessment of risk of extinction we calculated the Extent of Occurrence (EOO), defined by IUCN (2013a) as the area contained within the shortest continuous boundary that can be drawn to encompass all the known, inferred or projected sites of present occurrence of a taxon, excluding cases of vagrancy, and the Area of Occupancy (AOO), defined as the area that is occupied by a taxon within the EOO, excluding cases of vagrancy. IUCN recommends using a grid cell 2–3 km^2 when applying Criterion B (geographical range; Callmander et al., 2007; IUCN, 2013a). However, the populations of *D. ombet* are so scattered that a global AOO is not representative, especially as large portions of the Gebel Elba population are known to be unhealthy. We therefore used Criterion A, quantifying population size for a preliminary assessment of risk of extinction. To estimate the past and present distribution of *D. ombet* at a regional scale we recorded the locality of each tree in the wadi of Gebel Elba. We estimated the reduction in population size since 1997, using data for both living and dead trees (sensu Criterion A, IUCN, 2012).

Results

Distribution and population structure

The Nubian dragon tree was detected in 13 wadi, eight of which, located in the Elba Mountain massif, were surveyed in detail (Fig. 1); the remaining five are located near the Sudanese border. The c. 353 trees recorded in the eight wadi on Elba Mountain (Table 1) occurred at elevations of 450–950 m. Of the 46% (161 individuals) that were still alive, only 27% (96 individuals) were healthy. A majority of the trees were dead in all of the wadi studied, with the exception of wadi Marfay, where 71% (c. 44 individuals) were living (Table 1). The north-east of Gebel Elba Mountain (Tawella and Aretri wadi; Fig. 1) has the largest *Dracaena* woodland within the Park, with > 210 trees. However, there is evidence that these sites suffer from drought and unsuitable climatic conditions, which may account for the observed decline of > 60% in the populations that occur there, indicating that they will probably be lost in the near future. DBH measurements (Fig. 2) indicate an imbalanced age structure in populations of *D. ombet* on Gebel Elba Mountain, with c. 90% of the recorded individuals categorized as mid-age trees (DBH 35–140 cm) and < 1% (two individuals) categorized as young trees (DBH < 35 cm).

IUCN Red List assessment at regional and global scales

The EOO of *D. ombet* was calculated for the entire population within Gebel Elba National Park. Taking into

TABLE 1 Results of our survey of populations of Nubian dragon tree *Dracaena ombet* in eight wadi of the Gebel Elba Mountain in south-east Egypt (Fig. 1), with wadi name and location, number of trees, percentage of surviving trees, percentage decline, past and current areas of distribution, and percentage decline in distribution.

Wadi	No. of trees	% surviving trees	% decline	Past area (km^2)	Current area (km^2)	% decline in distribution
Aedieb Hills	5	80	20	0.148	0.132	10.81
Aedieb	12	25	75	0.032	0.004	87.50
Akaw	10	80	20	0.040	0.028	30.00
Aretri	148	40	60	0.169	0.128	24.26
Darawina	17	41	59	0.138	0.008	94.20
Marafay	62	71	29	0.227	0.167	26.43
Shtet	29	52	48	0.036	0.014	61.11
Tawella	70	33	67	0.537	0.238	55.68
Total	353	46	54	1.327	0.719	45.82

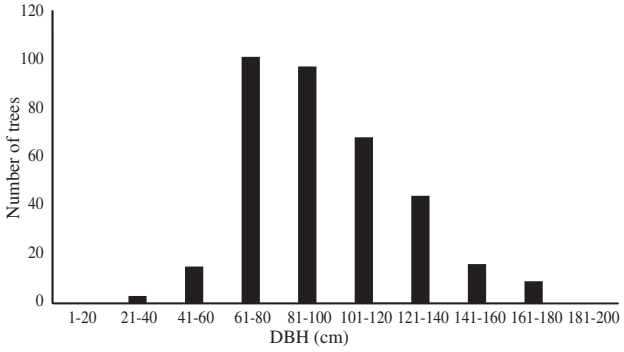

FIG. 2 Number of individuals of the Nubian dragon tree *Dracaena ombet* in each DBH class.

account the isolated Shendieb Mountain (located c. 20 km from the wadi surveyed at Gebel Elba), the EOO is c. 116 km^2. Because none of the area between these massifs is suitable for *D. ombet*, we also calculated an EOO excluding the small population on Shendieb Mountain, which is c. 24 km^2, or 0.3% of the area of the Park. To apply Criterion A (population reduction) we calculated the distribution of the entire population of the survey (present and past, by including dead trees). Our estimate suggests that *D. ombet* occupied an AOO of 1.327 km^2 as recently as 1997 but now occupies only 0.719 km^2, indicating a loss of 45.9% of its range in the Gebel Elba Mountains (Table 1). As almost no regeneration is occurring and only 25% of the trees appear to be healthy we predict that all subpopulations are likely to disappear within a decade (i.e. within the time frame covered by Criterion A; IUCN, 2012). We estimate that *D. ombet* is likely to decline by > 80% in this time frame and consequently we categorize *D. ombet* as Critically Endangered under Criterion A3c (IUCN, 2012).

Discussion

The flagship species *D. ombet* (Vincent, 2008) has a fragmented distribution throughout the Gebel Elba massif, a pattern resembling that seen in other species of dragon tree, such as the Arabian dragon tree *D. serrulata*, which grows in scattered populations on the western and southern escarpments of the Arabian Peninsula (Llewellyn et al., 2010). This type of distribution pattern reflects the ecology of these plants, which are adapted to specific edaphic and ecological conditions, such as limestone karsts (e.g. *D. jayniana* in Thailand; Wilkin et al., 2012). Pressure from human activities has relegated most dragon trees to inaccessible sites, such as steep cliffs in the Canary Islands and Morocco, where *D. draco* persists today. The highest percentage of healthy individuals of *D. ombet* in Gebel Elba National Park is found on steep slopes of the Aedieb Hills, on solid basement rock with extensive cracks and fissures. These relicts of the Mio-Pliocene Laurasian subtropical forests are now rare, partly as a result of the climatic changes of the late Pliocene that caused desertification in North Africa (Quetzel, 1978; Mies, 1996), which explains why *D. ombet* is now restricted to a narrow set of microhabitats.

The population of *D. ombet* on Gebel Shindeeb contains a high proportion of adult individuals, most of which are unhealthy. Extended periods of drought combined with high temperatures are clearly inhibiting regeneration (El Azzouni, 2003). Populations on the eastern slopes of Okoam Wahadel in Erkwit, Sudan, are facing similar challenges (Mohammed, 2004), as are those of *D. serrulata* in the Najran Mountains of western Saudi Arabia (Llewellyn, 2009). Likewise in Socotra *D. cinnabari* shows low levels of regeneration and a population structure skewed towards mature individuals (Adolt & Pavlis, 2004). These marginal climatic conditions coupled with increasing human pressure are important factors affecting the status of the Nubian dragon tree in the Elba Mountains. The population decline is closely correlated with the periods of drought that have affected the area since 1950, especially during the 1960s–1980s (Hobbs, 1992). Healthy populations of *D. ombet* are found only in inaccessible areas, in particular the Aedieb Hills. Attorre et al. (2007) recorded regeneration and a healthy population of *D. cinnabari*

at higher altitudes in Socotra, at similarly inaccessible sites that receive adequate rainfall.

All of the African dragon tree species are categorized as threatened on the IUCN Red List (2013b) but all except one of these assessments, that for *D. cinnabari*, are based on the outdated v. 2.3 of the Red List Categories and Criteria (IUCN, 1994) and need to be updated using newly compiled data and v. 3.1 of the Categories and Criteria (IUCN, 2012). The Arabian Plants Red List authority has recategorized *D. cinnabari* as Vulnerable (using criteria B2ab[iii]) based on data from Adolt & Pavlis (2004) and Attorre et al. (2007). *D. ombet* is categorized as Endangered (based on criteria A1cd; WCMC, 1998) but at a regional level in Gebel Elba National Park we assess it to be Critically Endangered under criterion A3c, based on IUCN (2012). Our study shows that populations are scattered and several are declining, with only 27% healthy trees and almost no regeneration. The skewed age class structure of these populations suggests that the Nubian dragon tree is facing extinction in the wild. At a global scale we project that *D. ombet* is facing a similar situation throughout its range. Based on our results and other available information we regard the Nubian dragon tree to be globally Endangered (based on criterion A3c), using v. 3.1 of the IUCN Red List Categories and Criteria (2012).

It seems likely that a major cause of the decline in the extent and quality of the woodland habitats in which *D. ombet* occurs is the gradual drying of this part of southern Egypt (Springuel, 2006). To support the development of a programme to conserve *D. ombet* in Africa, comprehensive field studies are required to assess the current status of populations at all known localities for which updated field data are lacking, especially those in regions such as Bale Mountain in Ethiopia, Hargesia in Somaliland, Goda and Hemed Mountains in Djibouti, and Erkwit in Sudan. Improving data on the distribution of this species will facilitate more accurate distribution modelling (Guisan et al., 2007). Because montane plants are particularly susceptible to the effects of climatic change (Walther et al., 2002; Thuiller et al., 2005), detailed studies to predict the response of *D. ombet* to this pressure are essential for in situ conservation planning and action. Developing a better understanding of the ecology of *D. ombet* and implementing an appropriate conservation management strategy would be further supported by population genetic studies. It will also be necessary to clarify the taxonomic status of *D. ombet* with regard to *D. serrulata*. Finally, ethno-botanical research would also be of value to understand the socio-economic importance of this species. These complementary lines of research are needed to develop and reinvigorate a traditional conservation system in which *D. ombet* would be featured as a flagship species to promote biodiversity conservation and sustainable use in the threatened areas where the Nubian dragon tree is found (Hall et al., 2010).

Acknowledgements

We thank the communities of the Gebel Elba National Park, without whom this project would not have been possible; the Conservation Leadership Programme for their continuous support; M. Fouda, Director of Nature Conservation Sector, and the Gebel Elba National Park staff for their support and assistance; Mohammed Gad, Mahmoud Hanafy, Samy Zalat, and Adam Saadallah and his staff for their special assistance to the project team; the LIFE Red Sea Project and the Center for Documentation of Cultural and Natural Heritage, in particular the Director, Hala Barakat, for their cooperation; Shaheer Youstos, Cloudia Yostso, and the Off Road Egypt Company for their support; and Mike Maunder and Pete Lowry for their constructive comments on the article.

References

Abu Al-Izz, M.S. (1971) *Landforms of Egypt*. American University, Cairo, Egypt.

Adolt, R. & Pavlis, J. (2004) Age structure and growth of *Dracaena cinnabari* populations on Socotra. *Trees*, 18, 43–53.

Attorre, F., Francesconi, F., Taleb, N., Scholte, P., Saed, A., Alfo, M. & Bruno, F. (2007) Will dragonblood survive the next period of climate change? Current and future potential distribution of *Dracaena cinnabari* (Socotra, Yemen). *Biological Conservation*, 138, 430–439.

Audru, J., Cesar, G., Forgiarini, G. & Lebrun, J. (1987) *La Végétation et les potentialités pastorales de la République de Djibouti*. Institut d'Elevage et de Médecine Vétérinaire des Pays Tropicaux, Maisons-Alforts, France.

Bos, J. (1997) Dracaena. In *Flora of Ethiopia and Eritrea* (eds S. Edwards, S. Demissew & I. Hedberg), pp. 76–79. The National Herbarium, Addis Ababa University, Ethiopia & The Department of Systematic Botany, Uppsala, Sweden.

Bos, J. (1998) Dracaena. In *The Families and Genera of Vascular Plants, Volume III* (ed. K. Kubitzki), pp. 238–241. Springer–Verlag, Berlin Heidelberg, Germany.

Callmander, M.W., Schatz, G.E., Lowry, II, P.P., Laivao, M.O., Raharimampionona, J., Andriambololonera, S. et al. (2007) Identification of priority areas for plant conservation in Madagascar using Red List criteria: rare and threatened Pandanaceae indicate sites in need of protection. *Oryx*, 41, 168–176.

CBD (Convention on Biological Diversity) (2011) *Global Strategy for Plant Conservation*. Http://www.cbd.int/gspc/ [accessed 28 April 2014].

Conservation International (2013) *Horn of Africa*. Http://www.conservation.org/where/priority_areas/hotspots/africa/Horn-of-Africa [accessed 14 July 2013].

El Azzouni, M. (2003) Conserving *Dracaena ombet*, Egypt's dragon tree. *Plant Talk*, 34, 38–39.

Friis, I. (1992) *Forests and Forest Trees of Northeast Tropical Africa: Their Natural Habitats and Distribution Patterns in Ethiopia, Djibouti and Somalia*. Royal Botanic Gardens, Kew, London, UK.

Friis, I. & Lawesson, J.E. (1993) Altitudinal zonation in the forest tree flora of northeast tropical Africa. *Opera Botanica*, 121, 125–127.

Ghazali, U., El Baily, H., Dora, A., Arkeeb, H.H., Aoud, M., Ossman, G. et al. (2008) *The Globally Endangered* Dracaena ombet *Monitoring and Assessment Project in Gabel Elba Protected*

Area, Egypt. Unpublished report. Conservation Leadership Programme, Egypt.
Ghabbour, S.I. (1997) *Identification of Potential Natural Heritage Sites in Arab Countries*. Report to the National UNESCO Commission, Cairo, Egypt.
Guisan, A., Graham, C.H., Elith, J., Huettmann, F. & NCEAS Species Distribution Modelling Group (2007) Sensitivity of predictive species distribution models to change in grain size. *Diversity and Distributions*, 13, 332–340.
Hall, M., Neale, S., Al-Abbasi, T.M. & Miller, A.G. (2010) Arabia's tallest trees: ecology, distribution and conservation status of the regionally endangered tree species *Mimusops laurifolia*. *Nordic Journal of Botany*, 28, 240–245.
Hobbs, J.J. (1992) *Bedouin Life in the Egyptian Wilderness*. University of Texas Press, Austin, USA.
IUCN (1994) *IUCN Red List Categories and Criteria v. 2.3*. IUCN Species Survival Commission, Gland, Switzerland & Cambridge, UK.
IUCN (2012) *IUCN Red List Categories and Criteria v. 3.1*. IUCN Species Survival Commission, Gland, Switzerland & Cambridge, UK.
IUCN (2013a) *Guidelines for Using the IUCN Red List Categories and Criteria v. 10*. Http://www.iucnredlist.org/documents/RedListGuidelines.pdf [accessed 14 July 2013].
IUCN (2013b) *IUCN Red List of Threatened Species v. 2013.1*. Http://www.iucnredlist.org [accessed 14 July 2013].
Kassas, M. (1956) The Mist Oasis of Erkwit, Sudan. *Journal of Ecology*, 44, 180–194.
Llewellyn, A. (2009) *Conservation of the Endangered Arabian Dragon Tree* Dracaena serrulata *in Saudi Arabia*. Unpublished report. Prescott College, Prescott, USA.
Llewellyn, O.A., Hall, M., Miller, A.G., Al-Abbasi, T.M., Al-Wetaid, A.H., Al Harbi, R.J. et al. (2010) Important plant areas in the Arabian Peninsula: 1. Jabal Qaraqir. *Edinburgh Journal of Botany*, 67, 37–56.
Magin, C. (ed.) (1999) *Monographie nationale de la diversité biologique de Djibouti*. Direction de l'Environnement, Ministère de l'Habitat, de l'Urbanisme, de l'Environnement et de l'Aménagement du Territoire, Djibouti & UICN, Nairobi, Kenya.
Marrero, A., Almeida, R.S. & Gonzàlez-Martìn, M. (1998) A new species of the wild dragon tree, *Dracaena* (Dracaenaceae) from Gran Canaria and its taxonomic and biogeographic implications. *Botanical Journal of the Linnaean Society*, 128, 291–314.
Mies, B.A. (1996) The phytogeography of Socotra: evidence for disjunctive taxa, especially with Macaronesia. In *Proceedings of the First International Symposium on Socotra Island: Present and Future* (ed. H.J. Dumont), pp. 83–105. United Nations Publications, New York, USA.
Mohammed, A.M. (2004) *Feasibility Study Report on Conservation of the* Dracaena ombet*, the Red Sea Hills, Sudan*. SOS Sahel International Sudan Programme, Oxford, UK.
Mwachala, G. & Cheek, M. (2012) *Dracaena mokoko* sp. nov. (Dracaenaceae–Ruscaceae/Asparagaceae) a critically endangered forest species from Mokoko, Cameroon. *Nordic Journal of Botany*, 30, 389–393.
Mwachala, G., Cheek, M., Fischer, E. & Muasya, A.M. (2007) A new species of *Dracaena* L. (Dracaenaceae–Ruscaceae) from Mt Kupe and the Bakossi Mts, Cameroon. *Kew Bulletin*, 62, 613–616.
Mwachala, G. & Fisher, E. (2013) *Dracaena rosulata* (Asparagaceae) —a new species from D.R. Congo. *Phytotaxa*, 88, 6–8.
NCDC (National Climatic Data Center) (2013) *Global Historical Climatology Network*. Http://www.ncdc.noaa.gov/oa/climate/ghcn-daily/index.php [accessed 14 July 2013].
Quetzel, P. (1978) Analysis of the flora of the Mediterranean and Saharan Africa. *Annals of the Missouri Botanical Garden*, 65, 479–534.
Springuel, I. (2006) *The Desert Garden: A Practical Guide*. American University in Cairo Press, Cairo, Egypt.
Thuiller, W., Lavorel, S., Araújo, M.B., Sykes, M.T. & Prentice, I.C. (2005) Climate change threats to plant diversity in Europe. *Proceedings of the National Academy of Sciences of the United States of America*, 102, 8245–8250.
Thulin, M. (1995) Dracaenaceae. In *Flora of Somalia, Volume 4* (ed. M. Thulin), pp. 27–29. Royal Botanic Gardens, Kew, London, UK.
Vincent, P. (2008) *Saudi Arabia: An Environmental Overview*. Taylor & Francis Group, London, UK.
Walther, G.R., Post, E., Convey, P., Menzel, A., Parmesan, C., Beebee, T.J.C. et al. (2002) Ecological responses to recent climate change. *Nature*, 416, 389–395.
WCMC (World Conservation Monitoring Centre) (1998) *Dracaena ombet*. In *IUCN Red List of Threatened Species v. 2014.1*. Http://www.iucnredlist.org [accessed 13 June 2014].
Wilkin, P., Suksathan, P., Keeratikiat, K., Van Welzen, P. & Wiland-Szymańska, J. (2012) A new threatened endemic species from central and northeastern Thailand, *Dracaena jayniana* (Asparagaceae: tribe Nolinoideae). *Kew Bulletin*, 67, 697–705.

Biographical sketches

Mohamed Kamel Ahmed's research interests include plant community and vegetation analysis, and the eco-physiological response to drought and salinity of the native plants in arid regions. Usama Mohammed Ghazaly has experience in the monitoring and conservation of plant diversity at Gebel Elba National Park, as well as in community work in remote rural areas of Egypt. Martin Callmander is interested in the systematics of various plant families and plant biogeography. He has considerable experience in IUCN Red Listing and in using botanical data in support of conservation in biodiversity hotspots.