



## Article

### Stable citations for herbarium specimens on the internet: an illustration from a taxonomic revision of *Duboscia* (Malvaceae)

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#### Abstract

A taxonomic revision of *Duboscia* (Malvaceae) with two species, *D. macrocarpa* and *D. viridiflora*, is presented and used to demonstrate a mechanism for linking from revisions to specimens held in herbaria using HTTP URIs. The implementation of this mechanism at the Royal Botanic Garden Edinburgh (E) is used as an example. Advantages of this approach include near universal support amongst web-connected devices. Hindrances to widespread adoption of such an approach are also discussed.

#### Introduction

Citation of sources is a requirement of good scientific writing. In paper-based publications, references to other works are designed to be read by a user who will visit a library to retrieve the target work. As journals move on-line, these references are increasingly hyperlinks of the kind used elsewhere on the World Wide Web. A reader simply clicks the link to gain access to the target work. Although there are many works still only in paper form, many publishers and complex copyright issues, it seems likely this way of navigating the literature will become ubiquitous.

Taxonomic publications also cite specimens. These references are designed for a human to find the associated specimen in a herbarium. They typically consist of collector name, collector number and Index Herbariorum code. Many herbaria are now digitising their holdings and making them available on-line. This digitisation process often includes high resolution images of the specimens. It seems reasonable that the reader of a taxonomic publication should expect to click on a reference to a specimen and see an image of that specimen immediately, just as they do with references to written works.

This paper contains linked references for specimens stored at the Royal Botanic Garden Edinburgh (E). By clicking on the specimen reference in a web browser or PDF viewer, the user will be taken to a web page containing more information and a zoomable, high-resolution image of the specimen. It is our intention that this paper serve as an example of how to link to our specimens, and—should it prove successful—a model for how other herbaria could provide specimen linking mechanisms. In this paper we concentrate on the linking method used at RBGE, and we do not attempt to link to the specimens cited from other collections.

#### Introduction to the revision

*Duboscia* (Bocquillon, 1866) is a small genus of trees in the family Malvaceae (formerly placed in Tiliaceae), found in forest from the Ivory Coast to the Democratic Republic of Congo. We follow the APG III (2009) circumscription of Malvaceae in this paper but note that this is not followed by all authors, for example Cheek (2007). *Duboscia* has been placed in the subfamily Grewioideae (Bayer & Kubitzki 2003). We are not aware of any DNA sequences for the genus and it was not included in molecular studies of the Malvaceae s.l. (Judd & Manchester 1997, Bayer et al. 1999 and Alverson et al. 1999).

During inventory work in the Sangha Trinational area (a series of adjacent protected areas along the borders of the Central African Republic, Cameroon and Republic of Congo), it was noted that there was some disagreement between the observations of the one of the authors (DJH) and the literature, as to how many species were in the genus and how to separate them. In particular, the key by Keay (1958) did not work (Harris 2002), and the number of species in the genus varied from one to three.

*Duboscia macrocarpa* was considered as the only species in the genus by Cheek et al. (2004, 2011), Keay (1989), Lebrun & Stork (1997) and Hawthorne & Jongkind (2006), with *D. viridiflora* in synonymy. Lebrun & Stork (2003) subsequently changed their view of *Duboscia* to include two species, *D. macrocarpa* and *D. polyantha*, which they had previously placed in synonymy with *D. macrocarpa*. *D. polyantha* was also accepted by Louppe et al. (2008), who additionally recognised *D. macrocarpa* and *D. viridiflora* making a total of three species. In contrast, Harris (2002), Sosef et al. (2006), Harris & Wortley (2008) and Wilczek (1963) all treated the genus *Duboscia* as having two species, *D. macrocarpa* and *D. viridiflora*. These differences in taxonomic opinion were the reason for carrying out the revision of this genus, as part of a wider investigation on the provision of botanical information online (Drinkwater, 2011).

## Results of taxonomic revision

From examination of material at BR, E, K and WAG it was concluded that the genus consists of two species: *Duboscia macrocarpa* and *D. viridiflora*. In general the two species can be easily separated from each other with a combination of characters. However, there were a few specimens which proved harder to determine, and for which the characters seemed to be intermediate. These were typically poorer quality, infertile specimens, and fallen leaves collected from under the tree. Seedling and sapling specimens were also difficult to determine with certainty. Floral and fruit characters give the clearest separation between these two species, although stem and leaf pubescence was often enough to separate them. Unless otherwise stated, colours are given for dried material.

The inflorescences consist of 0.5–3 cm long peduncles subtending a cluster of bracts below the pedicels (which are much shorter than the peduncles) and flowers. When examining the inflorescences, care should be taken to distinguish bracts from sepals. The petals are extremely small and not usually visible in specimens without dissecting the flower. The flowers of the two species show a difference in the colour of the calyx in dried specimens. Those of *D. macrocarpa* are quite distinct in that most specimens present obvious dense brown hairs. In *D. viridiflora*, the hairs on the outside of the calyx are shorter and lighter coloured. The inflorescences of the two species are also distinguishable by the difference in the length of the peduncle, which was long and slender in *D. viridiflora* and shorter and stouter in *D. macrocarpa*.

The fruit also provides good characters for separating the two species. The fruit of *D. macrocarpa* has a dense cover of stellate hairs, which can be readily seen when examined with a  $\times 10$  hand lens, and this fits some descriptions of the species in the literature that describe the fruit as velvety. Compared to this, the fruits of *D. viridiflora* have a more granular or rough appearance when examined with a  $\times 10$  hand lens. However, when the fruit of the two species are viewed with a higher magnification (e.g.  $\times 40$ ), the differences in the surface textures become harder to distinguish as the granular texture of *D. viridiflora* under  $\times 10$  is revealed as stellate hairs at the higher magnification.

Some characters of the leaves and petioles are useful for distinguishing the two species, however they are best used in conjunction with fertile characters, and when comparing specimens of the two species. *D. macrocarpa* tends to have a shorter petiole, less than 1 cm long. The petiole and main stems are covered with dense stellate hairs and long straight hairs, reddish-brown in colour. In *D. viridiflora* the petiole tends to be longer (over 1 cm long) and, along with the main stems, is covered in shorter stellate hairs; straight hairs are absent in this species. The density of stellate hairs on young twigs can also be useful in separating the two species. The stellate hairs are shorter and sparser in *D. viridiflora* and longer and denser in *D. macrocarpa*. The differences in the types of hair present can also be seen on the leaves of the two species, with *D.*

*macrocarpa* having both straight and stellate hairs on the underside of the leaf, particularly on the tertiary veins, whereas *D. viridiflora* only has stellate hairs, which tend to have shorter arms than those seen in *D. macrocarpa*. The hairs of *D. macrocarpa* seem to be lost easily in dried material, with older stems often appearing hairless; the hairs of *D. viridiflora* are retained in dried material.

There were also differences noticed in the texture of the leaves, with the specimens of *D. viridiflora* often having a papery feel to them, and a smoother underside. The specimens of *D. macrocarpa* appear to have thicker leaves, with a rougher texture to the underside. With sterile material, those characters given above for leaves and stems are not always clear, e.g. it became apparent when taking measurements of the specimens that the length of the petiole was often on the cusp of being one side of 1cm or the other, with both species having some measurements just above, or just below the lengths stated in the description and key. The presence of hairs is also sometimes difficult to determine, particularly in older specimens, from which they often seem to have been lost. All these sterile characters are most useful when comparing individuals of the two species, rather than for identifying a single specimen, because the differences are relative, and most apparent when specimens of the two are compared side by side.

Another character used in the literature, is the number of flowers and bracts per inflorescence. The combination of the number of bracts and flowers was used by Keay (1958) to separate two species of *Duboscia*, although this character was later described as “unworkable in both the field and the herbarium” by Harris (2002). Observations made during the examination of the specimens showed the numbers of bracts and flowers to vary within each species, and to overlap between the two species so we could not use these numbers to separate the species.

As the genus has not been previously included in molecular studies, it would be useful if this were done, to clarify the position of the genus within Malvaceae. As the two species grow sympatrically and overlap in habitat type, it would be interesting to identify specimens where there were difficulties in determining the species, to see whether there is evidence of hybridisation or introgression.

The specimens cited in this revision as held at E, are listed in Table 1, along with Hypertext Transport Protocol Uniform Resource Identifiers (HTTP URIs) to the specimens on the Royal Botanic Garden Edinburgh’s herbarium web site. Clicking on these URIs will lead to more information about the specimens and images, provided an internet connection is available. Similar links are also included in the *Additional Specimens Examined* section for each species.

## Taxonomic Treatment

*Duboscia* Bocquillon (1866: 50).

Type:—*Duboscia macrocarpa* Bocquillon.

Tree, with fluted bole. **Leaves:** alternate, entire, dentate in young specimens, often whitish below. **Inflorescences:** axillary cymes opposite leaves, enclosed by involucre bracts, resembling sepals. **Flowers:** sepals boat-shaped, corolla very small. **Fruit:** ellipsoid, ribbed, fibrous, indehiscent.

## Key to the species of *Duboscia*

1. Inflorescence reddish-brown in colour. Fruit with short, stellate hairs, which give it a velvety appearance at ×10 magnification. Short stellate hairs on twigs, denser than in *D. viridiflora*. Long straight hairs on twigs, occasionally falling off in older material. Petioles usually less than 1 cm long .....*D. macrocarpa*
- Inflorescence grey-green in colour. Fruit with very short hairs which give it a granular appearance at ×10 magnification. Short, stellate hairs on twigs, sparser than in *D. macrocarpa*. Long straight hairs on twigs absent. Petioles usually more than 1 cm long .....*D. viridiflora*

**TABLE 1.** HTTP URIs of cited specimens held at Edinburgh (E)

Species	Collector Name and No.	HTTP URI
<i>D. macrocarpa</i>	Goldsmith, M. 207	<a href="http://data.rbge.org.uk/herb/E00435912">http://data.rbge.org.uk/herb/E00435912</a>
<i>D. macrocarpa</i>	Harris, D.J. 5093	<a href="http://data.rbge.org.uk/herb/E00435914">http://data.rbge.org.uk/herb/E00435914</a>
<i>D. macrocarpa</i>	Harris, D.J. 5488	<a href="http://data.rbge.org.uk/herb/E00435922">http://data.rbge.org.uk/herb/E00435922</a>
<i>D. macrocarpa</i>	Harris, D.J. & Fay, J.M. 829	<a href="http://data.rbge.org.uk/herb/E00435918">http://data.rbge.org.uk/herb/E00435918</a>
<i>D. macrocarpa</i>	Harris, D.J. & Fay, J.M. 848	<a href="http://data.rbge.org.uk/herb/E00435917">http://data.rbge.org.uk/herb/E00435917</a>
<i>D. macrocarpa</i>	Harris, D.J. & Fay, J.M. 1540	<a href="http://data.rbge.org.uk/herb/E00435913">http://data.rbge.org.uk/herb/E00435913</a>
<i>D. viridiflora</i>	Fangounda, J. 506	<a href="http://data.rbge.org.uk/herb/E00435920">http://data.rbge.org.uk/herb/E00435920</a>
<i>D. viridiflora</i>	Fay, J.M. & Harris, D.J. 8548	<a href="http://data.rbge.org.uk/herb/E00435911">http://data.rbge.org.uk/herb/E00435911</a>
<i>D. viridiflora</i>	Harris, D.J. 4960	<a href="http://data.rbge.org.uk/herb/E00435923">http://data.rbge.org.uk/herb/E00435923</a>
<i>D. viridiflora</i>	Harris, D.J. 6016	<a href="http://data.rbge.org.uk/herb/E00435919">http://data.rbge.org.uk/herb/E00435919</a>
<i>D. viridiflora</i>	Harris, D.J. 7716	<a href="http://data.rbge.org.uk/herb/E00435924">http://data.rbge.org.uk/herb/E00435924</a>
<i>D. viridiflora</i>	Harris, D.J. 7969	<a href="http://data.rbge.org.uk/herb/E00435925">http://data.rbge.org.uk/herb/E00435925</a>
<i>D. viridiflora</i>	Harris, D.J. & Fay, J.M. 30	<a href="http://data.rbge.org.uk/herb/E00435915">http://data.rbge.org.uk/herb/E00435915</a>
<i>D. viridiflora</i>	Harris, D.J. & Fay, J.M. 730	<a href="http://data.rbge.org.uk/herb/E00435916">http://data.rbge.org.uk/herb/E00435916</a>
<i>D. viridiflora</i>	Moukassa, G. 43	<a href="http://data.rbge.org.uk/herb/E00435926">http://data.rbge.org.uk/herb/E00435926</a>
<i>D. viridiflora</i>	Nzolani Silaho, F.O. 393	<a href="http://data.rbge.org.uk/herb/E00435921">http://data.rbge.org.uk/herb/E00435921</a>
<i>D. viridiflora</i>	Nzolani Silaho, F.O. Moutsamboté, J.-M. & Harris, D.J. 2	<a href="http://data.rbge.org.uk/herb/E00435909">http://data.rbge.org.uk/herb/E00435909</a>
<i>D. viridiflora</i>	Remis, M. 112-95	<a href="http://data.rbge.org.uk/herb/E00435908">http://data.rbge.org.uk/herb/E00435908</a>
<i>D. viridiflora</i>	Zenker, G.A. 923	<a href="http://data.rbge.org.uk/herb/E00421511">http://data.rbge.org.uk/herb/E00421511</a>
<i>D. viridiflora</i>	Zenker, G.A. 1799	<a href="http://data.rbge.org.uk/herb/E00421512">http://data.rbge.org.uk/herb/E00421512</a>
<i>D. viridiflora</i>	Zenker, G.A. 1925	<a href="http://data.rbge.org.uk/herb/E00421507">http://data.rbge.org.uk/herb/E00421507</a>
<i>D. viridiflora</i>	Zenker, G.A. 3268	<a href="http://data.rbge.org.uk/herb/E00421510">http://data.rbge.org.uk/herb/E00421510</a>
<i>D. viridiflora</i>	Zenker, G.A. 3310	<a href="http://data.rbge.org.uk/herb/E00421508">http://data.rbge.org.uk/herb/E00421508</a>
<i>D. viridiflora</i>	Zenker, G.A. 4165	<a href="http://data.rbge.org.uk/herb/E00421509">http://data.rbge.org.uk/herb/E00421509</a>

**FIGURE 1.** *Duboscia macrocarpa*. The short, stout petiole and long, straight hairs on the petiole and stem can be clearly seen.

1. *Duboscia macrocarpa* Bocq., Bocquillon (1866: 50). Type:—GABON, 1862, *G. Mann 1759* (holotype K!).

= *Duboscia polyantha* Pierre ex Chev., Chevalier (1917: 81). Type:—GABON, 1896, *Klaine 354* (holotype K!).

= *Diplanthemum brieyi* De Wild., De Wildeman (1915: 65). Type:—DEMOCRATIC REPUBLIC OF CONGO, no date, *J. de Brieyi 226* (holotype BR!).

Tree to 30 m; trunk to 90 cm dbh, often fluted; bark grey-brown; young twigs with dense reddish-brown stellate and long straight hairs. **Leaves** alternate, entire, to 24 cm long, to 11 cm wide; petioles usually less than 1 cm in length, usually with dense reddish-brown straight hairs; medium-bright green above, greyish green and rough below, tertiary veins with stellate and straight hairs. **Inflorescence** an axillary cyme opposite leaves. Flowers enclosed by involucre bracts, pale green to dull pink in colour when fresh, reddish-brown when dried; pedicel less than 1 cm long, stout in appearance, bract pale green, calyx pink-reddish brown when fresh, turning darker when dried, covered with dense brown hairs. **Fruits** indehiscent, ribbed, brown-green when fresh, red-orange when dried, surface looks velvety, with stellate hairs visible at  $\times 10$  magnification.

**Distribution:**—Angola, Cameroon, Central African Republic, Republic of Congo, Democratic Republic of Congo, Equatorial Guinea, Gabon, Nigeria (Map, Fig. 2.)

**Habitat:**—Forest including disturbed areas and river banks.

**IUCN conservation assessment:**—Least Concern (LC). This species has a large range, is locally common and recent herbarium specimens have been collected.

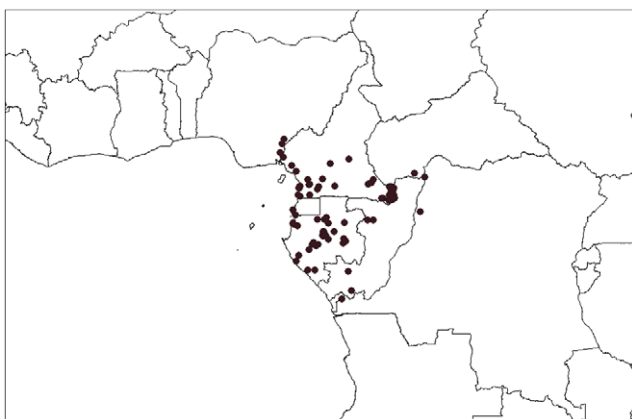


FIGURE 2. Distribution map for *Duboscia macrocarpa*.

**Additional specimens examined:**—ANGOLA: Cabinda, *J. Gossweiler 6560* (K); Cabinda, Chilungo, 1919, *J. Gossweiler 7656* (K). CAMEROON: Ma'an, road Ma'an- Bitoto, plantations bordering road just before entering Ma'an ville, 2°22' N, 10°38' E Alt: 500m, 12 February 2001, *T.R. van Andel M. Menguele 3136* (WAG); Dipikar, road Bongola-Ntem River, 2°17' N, 9°57' E Alt: 60m, 2 July 2001, *T.R. van Andel B. Mva 3811* (WAG); Bitya, 3°00' N, 12°21' E, 19 January 1921, *G.L. Bates 1702* (K); North bank of Lobe river, 9km S of Kribi, 2°52' N, 9°54' E, 14 October 1968, *J.J. Bos 3085* (K, WAG); E of Bwambe Catholic Mission, 6 km S of Kribi, 2°53' N, 9°54' E, 8 November 1968, *J.J. Bos 3252* (WAG); About 13km from Kribi, Edea road, 3°01' N, 9°57' E, 7 January 1969, *J.J. Bos 3569* (K, WAG); E of Kribi S bank of Kienke river, 2°56' N, 9°55' E, 12 May 1969, *J.J. Bos 4492* (K, WAG); Kribi beach, about 500 m N. of Kienke river mouth, 2°56' N, 9°54' E, November 1969, *J.J. Bos 5894* (WAG); 8 km SE of Ebaka, 50km NW of Bertoua, 4°53' N, 13°22' E Alt: 680m, 23 May 1961, *F.J. Breteler 1420* (K, WAG); About 10 km N of Kribi. Secondary forest, 11 July 1994, *F.J. Breteler 12773* (WAG); Korup national park, 5°01' N, 8°48' E Alt: 100m, 14 December 2005, *X.M. van der Burgt, J. Motoh 820* (K, WAG); Kribi, beach north of the Kienke river mouth, 2°57' N, 9°54' E, September 1997, *X.M. van der Burgt 202* (WAG); Korup National Park, P plot, subplot 23I, 5°01' N, 8°48' E Alt: 100m, 14 December 2005, *X.M. van der Burgt, J. Motoh 820* (K, WAG); environs de Douala, 4°03' N, 9°42' E, June 1917, *A.J.B. Chevalier, F. Fleury (leg) 33161* (WAG); Groß-Batanga, 2°51' N, 9°52' E, 6 August

1890, *M.J. Dinklage*, 713 (WAG); 2°51' N, 9°52' E, 21 December 1891, *M.J. Dinklage*, 713 (WAG); Douala, 4°03' N, 9°42' E, *Fleury* 33161 (K); 1935, *Foury* 91 (K); Lac Lobeke Reserve, ca. 40 km west of Djembe. In *Gilbertiodendron dewevrei* forest north of road, 2°09' N, 15°44' E, 18 October 1998, *D.J. Harris*, *J.N. Asonganyi*, *A. Koufani* & *J.-M. Onana* 5997 (E); km 5 Yokadouma-Moloundou road, 3°28' N, 15°04' E Alt: 530m, 27 November 1982, *A.P.M. de Kruif* 736 (WAG); Left bank Boumba river 8km SW of Madjwe, which is 36km from Yokadouma to Moloundou, 3°13' N, 14°55' E Alt: 470m, 20 July 1965, *A.J.M. Leeuwenberg*, 6197 (K, WAG); 14km to the W of Masea (village 50km SSW of Yokadouma), 3°09' N, 14°43' E, 2 July 1963, *R. Letouzey* 5387 (K, WAG); Ekumbe Mofako, Alt: 200m, 21 May 1994, *J.-M. Mbani* 385 (K); Etwa, 95km NE of Yaounde, 4°33' N, 12°03' E, February 1914, *G.W.J. Mildbraed* 8189 (K); 28km on road Mbalmayo, 3°30' N, 11°30' E, 23 September 1953, *B. Mpom* 55 (K); 10km west of Banga, 4°25' N, 9°23' E Alt: 50m, 30 October 1985, *D.W. Thomas* 4882 (K); Campo, 2°22' N, 9°49' E, 1976, *J. Webb* 401 (K); 16 km on the road from Ebolowa to Minkok, 2°57' N, 11°15' E Alt: 640m, 12 June 1975, *J.J. de Wilde* 8287 (K, WAG); Hill facing N'Kolandom, 4 km on the road from N'Koemvone to Akoakas (counting from the crossing at N'Koemvone), 2°48' N, 11°10' E Alt: 750m, 3 February 1975, *J.J.F.E. de Wilde* 7950 (WAG); 16 km on the road from Ebolowa to Minkok. Short cut on the road to M'Balmayo, 2°57' N, 11°15' E Alt: 640m, 12 June 1975, *J.J.F.E. de Wilde* 8287 (K, WAG); 40Km S of Badjob, 50km SW of Eseka near the Nyong river, 3°08' N, 10°37' E, 18 December 1963, *W.J.O. de Wilde*, *B.E.E. de Wilde-Duyffes* 1530 (K, WAG); 40 km S. of Badjob, 50 km SW. of Eséka, near the Nyong river, 3°28' N, 10°30' E, 18 December 1963, *W.J.O. de Wilde*, *B.E.E. de Wilde-Duyffes* 1530 (K, WAG); Nyong river near the new bridge about 65km SSW of Eseka, 3°06' N, 10°34' E, 18 June 1964, *W.J.O. de Wilde*, *B.E.E. de Wilde-Duyffes* 2741 (K, WAG); c. 50 km South of Badjob, c. 60 km Southwest of Eseka. Along the Njong river, near the new bridge, 3°28' N, 10°30' E Alt: 200m, 18 June 1964, *W.J.O. de Wilde*, *B.E.E. de Wilde-Duyffes* 2741 (K, WAG).

CENTRAL AFRICAN REPUBLIC: Bai Hoku, 25 km E of Bayanga, 2°52' N, 16°28' E, 1995, *M. Goldsmith* 207 (E); Ndakan gorilla study area on trail from Njeke stream to Mambele clearing. Lowland forest with *Entandrophragma* spp, *Drypetes gossweileri* and *Irvingia excelsa*. Precp. 1400 m, 2°22' N, 16°12' E Alt: 350m, 2 June 1988, *D.J. Harris*, *J.M. Fay* 829 (E); Dzanga-Sangha Reserve. Ndakan gorilla study area from camp to above the Kénnié confluence on the East bank of the Sangha River. Riparian forest with *Uapaca heudelotii*, *Irvingia smithii* and *Trichilia retusa*. Precp. 1400 m, 2°21' N, 16°09' E Alt: 350m, 30 July 1988, *D.J. Harris*, *J.M. Fay* 848 (E, WAG); Dzanga-Sangha Reserve. 45 km South of Lidjombo, East bank of Sangha River from NDAKAN. Riparian forest with *Uapaca heudelotii* and *Irvingia smithii*. Precp. 1400 m, 2°21' N, 16°09' E Alt: 350m, 4 November 1988, *D.J. Harris*, *J.M. Fay* 1540 (E); Ca. 10 km from Kongana on the road to Bayanga, 20 km SE of Bayanga, 2°47' N, 16°23' E, 7 June 1994, *D.J. Harris* 5093 (E); Sangha-Mbaere, Kongana camp, 22 km SE of Bayanga, 2°47' N, 16°26' E, 7 March 1996, *D.J. Harris* 5488 (E); Sangha-Mbaere, Bai Hoku Camp, 25 km ESE of Bayanga, 2°52' N, 16°28' E, 15 May 1996, *D.J. Harris* 5529 (E); Safari camp at mouth of Babongo stream, 2°59' N, 16°13' E, 2 January 1998, *D.J. Harris* 5736 (E); Boukoko, 3°54' N, 17°56' E, 1949, *C. Tisserant (Équipe)* 1595 (WAG); *C. Tisserant* 16 (K, WAG); *C. Tisserant* 1595 (K, WAG); Boukoko, 3°54' N, 17°56' E, *C. Tisserant* 1708 (K); Bayanga, 2°54' N, 16°16' E, 5 March 1976, *Wraber* 101 (K).

REPUBLIC OF CONGO: Old road from PK257 to Mayoko, 21 May 1965, *A. Bouquet* 1380 (K); 13km N of Placongo village, 2°56'02" S, 13°18'24" E Alt: 467m, 6 October 2009, *E. Kami*, *C. Couch*; *X.M. van der Burgt*, *P. Manguila*, *P. Rostrand* & *R. Mayama* 72 (K); région de Mayoko, chantier forestier Aubeville, 4°16' S, 13°33' E, 15 March 1973, *P. Sita*, 3538 (WAG).

DEMOCRATIC REPUBLIC OF CONGO: Ganda Sundi, 4°52'00" S, 12°52'00" E, 1913, *C. de Briey* 226 (BR); Bodjambi (territory Bomongo), 1°14' N, 18°18' E, 16 March 1959, *C.M. Evrard* 5962 (BR, K); Libenge, 3°39' N, 18°38' E, October 1930, *J. Le Brun* 1531 (BR).

EQUATORIAL GUINEA. Sofoge, 1°20' N, 9°28' E, 21 May 1998, *Y. Y. Azizet Issembé* 25 (WAG); Nkolon Fangan, Alt: 450m, 30 January 1908, *G. Tessmann* 306 (K); Bebai, 27 August 1908, *G. Tessmann* 512 (K).

GABON: 14 km SE of Mitzic, FOREENEX forest exploitation, road from FOREENEX forestry camp to Madouaka village, c. 0°41'53" N, 11°38'31" E Alt: 481m, 7 November 2009, *P. Bissiengou*, *F.J. Breteler*, *R. Niangadouma* & *J.-N. Boussiengui* 746 (WAG); c. 27 km Kessipoughou-Lifouta Gare, 0°59' S, 12°57' E Alt: 600m, 24 November 1993, *F.J. Breteler*, *B.J.M. Breteler-Klein Breteler*, 12332 (WAG); about 5 km on road



**FIGURE 3.** *Duboscia viridiflora*, with longer petiole and short, stellate hairs on the petiole.

from Yombi to Mandji, 1°25' S, 10°35' E, 17 September 1997, *F.J. Breteler, M.E. Leal, J.-M. Moussavou & G. Nang-Essouma 13961* (WAG); Makande surroundings, c. 65 km SSW of Booué, 0°41' S, 11°55' E, 4 February 1999, *F.J. Breteler, G. Caballé, Y. Azizet Issembé, J.-M. Moussavou & O. Pascal 14915* (WAG); Makande surroundings, about 65 km SSW of Booué, 0°41' S, 11°55' E, 11 February 1999, *F.J. Breteler, G. Caballé, Y. Azizet Issembé, J.-M. Moussavou, O. Pascal & R.H.M.J. Lemmens 15001* (WAG); CIRMF (Lopé), 0°18' S, 11°40' E, 26 October 1987, *J.J. Dibata 337* (WAG); c. 1 km southwest of Akaka camp, 2°13'38" S, 9°40'40" E Alt: 5m, 15 May 2005, *D.J. Harris, K.E. Armstrong & R. Niangadouma 8668* (E, LBV, WAG); Doudou Mountains, Chantier SNF-Bakker, c. 2°51'30" S, 10°30'33" E Alt: 100m, 1 December 2003, *C.C.H. Jongkind, J.L.C.H. van Valkenburg, R. Niangadouma & A.J. Mabicka 5866* (WAG); Environs de Libreville, 0°25' N, 9°27' E, 1895, *T.-J. Klaine 192* (P); 1896, *T.-J. Klaine 354* (K, WAG); environs de Libreville, 0°25' N, 9°27' E, 4 November 1895, *T.-J. Klaine 354* (WAG); Libreville, 0°23' N, 9°27' E, 12 February 1902, *T.-J. Klaine 2702* (K); 0°23' N, 9°27' E, *T.-J. Klaine 3251* (K); Area around Nyanga, 1914, *G. Le Testu 1999* (K); Massif du Chaillu, Waka National Park, eastern slope canyon, 1°10' S, 11°05' E, 11 March 2005, *M.E. Leal, D. Nguema Ekomo, A. Moundounga & P. Bissiemou 403* (WAG); Louga river, 30km N of forestry camp Waka, which is situated about 30km SE of Sindara, 0°56' S, 10°55' E, 11 December 1983, *A.M. Louis, F.J. Breteler & J. de Bruijn 1275* (K); Muni river, 1°00' N, 9°38' E, August 1862, *G. Mann 1759* (K); Lope reserve S of Ayem, 0°25' S, 11°30' E Alt: 200m, 7 March 1989, *G. McPherson G. 13731* (K, WAG); Réserve de la Lopé, au sud d'Ayem; chantier SOFORGA, 0°25' S, 11°30' E Alt: 200m, 7 March 1989, *G.D. McPherson 13731* (WAG); Eastern border of Lopé-Okanda Reserve, along roads S of SEG lumber camp, W of Offoué River, 0°27' S, 11°45' E Alt: 200m, 17 May 1992, *G.D. McPherson 15788* (WAG); Near Booué-Makokou road, north of Koumameyong, along SHM lumber roads, 0°25' N, 11°55' E Alt: 200m, 31 January 1993, *G.D. McPherson 16120* (WAG); East of Lastoursville, near Bambidie, C.E.B. chantier. Tall forest, 0°49' S, 13°08' E Alt: 250m, 28 September 1996, *G.D. McPherson 16734* (MO, WAG); Ivindo National Park, Massouna 2000, route rivière Djidji, 0°10' S, 12°20' E, 2 May 2004, *A. Mougazi, 1611* (WAG); chantier Rougier-Océan, Oveng, 0°41' N, 11°09' E, 9 May 1985, *J.M. Reitsma, B. Reitsma, F.J. Breteler & A.M. Louis 942* (E, WAG);

Secondary vegetation between Ntoum and Donguila, 0°15' N, 9°47' E, 20 May 1986, *J.M. Reitsma, B. Reitsma 2260* (WAG); Primary rain forest, Réserve de la Lopé, chantier SOFORGA; inventory, 0°30' S, 11°33' E, 26 June 1986, *J.M. Reitsma, B. Reitsma 2368* (WAG); Libreville. Arboretum de Sibang, Parcelle I, 0°25' N, 9°28' E Alt: 50m, 11 January 2000, *E.L.A.N. Simons, R. Westerduijn 642* (WAG); c. ½km N of Evouta, 1°03'30" S, 11°11'28" E Alt: 400m, 19 March 2007, *M.S.M. Sosef, J.J. Wieringa, B. Nziengui, P. Bissiengou & E.P. Ngombou Mamadou 2416* (WAG); Komi, near Sindara. Forest with Aucoumea, 1°04' S, 10°48' E Alt: 100 - 400m, 17 June 1986, *D.W. Thomas, C.M. Wilks 6400* (WAG); Lopé-Okanda Reserve. Grand-Débardage Trail. Secondary growth bosque, c. 0°11'56" S, 11°34'34" E Alt: 238m, 2 November 2000, *G.M. Walters, J.R. Stone, B. Nziengui & J.-M. Moussavou 482* (WAG); Reserve de Lopé-Okanda, SEGC, Rue des Cascades, 0°11' S, 11°34' E Alt: 200m, 31 July 1990, *L.J.T. White, 57* (WAG); Rabi-Kounga, 7 km NNE of 'Checkpoint-Charlie', 1°48' S, 9°51' E Alt: 30m, 22 May 1992, *J.J. Wieringa, T. Nzabi, 1028* (WAG); c.35 km ENE of Lastoursville, 11 km on forestry road from Bambidie to Akieni, 0°39'19" S, 12°58'32" E Alt: 320m, 29 January 2008, *J.J. Wieringa, P.H. Hoekstra, R. Niangadouma & J.-N. Boussiengui 6253* (WAG); Lopé Forest Reserve. About 1 km. from the S.E.G.C. station, 0°11' S, 11°36' E Alt: 150m, 28 November 1995, *J.J.F.E. de Wilde, L.J.G. van der Maesen, H.P. Bourobou & J.-M. Moussavou 11488* (WAG); Lope reserve, 0°10' S, 11°35' E, April 1985, *L. Williamson 59* (K). NIGERIA. Ikom, 5°58' N, 8°42' E, 24 November 1934, *R. Catterall 58* (K); Ikom district. Afi river forest reserve, path from Boje to Iso Bendiga, 6°15' N, 8°51' E, 14 December 1950, *R.W.J. Keay 28256* (K); Oban, 5°19' N, 8°34' E, 15 January 1912, *P.A. Talbot, 1293* (K).

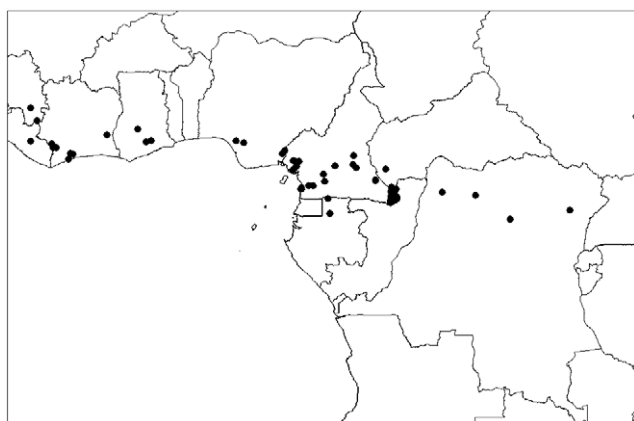
**2. *Duboscia viridiflora*** (K.Schum.) Mildbr., Mildbraed (1922: 59). *Diplantheum viridiflorum* K.Schum., Schumann (1897: 234). Type:—CAMEROON, Yaounde, no date, *Zenker 764* (holotype K!).

Tree to 25 m; trunk to 180 cm dbh, often deeply fluted; bark grey-brown; young twigs with short, sparse stellate, red-brown hairs. **Leaves** alternate, entire, to 22 cm long and 10 cm wide; petioles usually more than 1 cm in length; papery, medium-dark green, glossy above, pale green below, tertiary veins with sparse stellate hairs. **Inflorescence** an axillary cyme opposite leaves. Flowers enclosed by involucre bract, pale green in colour, when fresh, grey-green when dried; pedicel, more than 1 cm, slender in appearance; bract pale-pinkish green in fresh material, calyx pale green to white/cream. **Fruits** indehiscent, often ribbed, green-brown when fresh, red-orange when dried, surface looks granular when examined with a ×10 hand lens, stellate hairs only visible at or above ×40 magnification.

**Distribution:**—Cameroon, Central African Republic, Republic of Congo, Democratic Republic of Congo, Equatorial Guinea, Gabon, Ghana, Guinea, Ivory Coast, Nigeria. (Map, Fig. 4.)

**Habitat:**—Forest, including disturbed areas and river banks.

**IUCN conservation assessment:**—Least Concern (LC). This species has a large range, is locally common and recent herbarium specimens have been collected.



**FIGURE 4.** Distribution map for *Duboscia viridiflora*.



**Additional specimens examined:**—CAMEROON: Main road to Kumba mile 53, 4°50' N, 9°20' E, 6 April 1960, *J.K. Adebuseyi* 44012 (K); Batanga, 2°51' N, 9°52' E, 19 April 1895, *G.L. Bates* 185 (K); 6.5km S of Kribi, Gr. Batanga road, 2°53' N, 9°54' E, 30 October 1968, *J.J. Bos* 3174 (K, WAG); Yokadouma, 3°31' N, 15°03' E, 20 June 1961, *F.J. Breteler* 1530 (K, WAG); N'Kolbisson, 3°53' N, 11°27' E Alt: 700m, 12 March 1962, *F.J. Breteler* 2627 (K, WAG); 20 km W of Bertoua, between 1 and 10km N of Mbang, 4°34' N, 13°30' E Alt: 660m, 14 May 1962, *F.J. Breteler* 2944 (K, WAG); Kribi, beach north of the Kienke river mouth, 2°57' N, 9°54' E, September 1997, *X.M. van der Burgt* 446 (WAG); Bassin du Mungo, 4°27' N, 9°34' E, June 1917, *A.J.B. Chevalier, F. Fleury (leg)* 33443 (WAG); Boa Bakandu reserve, 4°48' N, 9°28' E Alt: 250m, 12 November 1986, *M. Etuge, D.W. Thomas*, 384 (K, WAG); Bassin du Mungo village of Mayouka, at 59km on the railway line to the N, 4°17' N, 9°24' E, July 1917, *Fleury* 33443 (K); West on Sangha river, precip. 1400 mm. Lowland forest with *Entandrophragma* spp. Sterculiaceae and *Megaphynium macrostachyum*, 2°21' N, 16°07' E Alt: 350m, 30 December 1987, *D.J. Harris, J.M. Fay* 30 (E); Lobeke Reserve. Road head at start of path to Small Bai, 29 October 1998, *D.J. Harris, J.N. Asonganyi, A. Koufani & J.-M. Onana* 6016 (E); Dengdeng, 5°12' N, 13°31' E, July, *Jacques-Félix, H.* 4597 (K, WAG); Dengdeng, 5°12' N, 13°31' E, July 1939, *H. Jacques-Félix* 4597 (WAG); 15km E of Dimako on Bertoua to Doume road, 4°22' N, 13°42' E, 11 June 1965, *A.J.M. Leeuwenberg* 5835 (K, WAG); Km 8 of road Yokadouma-Moloundou, 3°27' N, 15°03' E Alt: 520m, 15 July 1965, *A.J.M. Leeuwenberg* 6146 (WAG); 1 km W. of Kola, a village N. of Loum. 4°49' N 9°45' E, 4°49' N, 9°45' E Alt: 500m, 26 April 1972, *A.J.M. Leeuwenberg, C.C. Berg* 9741 (WAG); Bolifamba, 4°10' N, 9°18' E, March 1929, *T.D. Matland* 584 (K); Etwa 105km NE of Yaounde, 4°30' N, 12°13' E, February 1914, *G.W.J. Mildbraed* 8220 (K); Dengdeng, 5°12' N, 13°31' E, *P. Nana* 80 (K); A 4,5 km au Nord du village d'Ebom, piste villageoise, 3°06' N, 10°43' E Alt: 400m, 24 September 1996, *D. Ndoum* 127 (WAG); N'Kolbisson, 3°53' N, 11°27' E Alt: 600m, 30 May 1964, *W.J.O. de Wilde, B.E.E. de Wilde-Duyffes* 2632 (K, WAG); Centre agronomique N'Kolbisson, 8 km W. of Yaoundé, 3°53' N, 11°27' E Alt: 600m, 30 May 1964, *W.J.O. de Wilde, B.E.E. de Wilde-Duyffes* 2632 (K, WAG); Bipindi, 3°05' N, 10°25' E, *G.A. Zenker* 130 (WAG); Yaounde, 3°25' N, 11°31' E Alt: 800m, *G.A. Zenker, A. Staudt* 280 (K); 3°25' N, 11°31' E, *G.A. Zenker* 764 (K); Bipindi, 3°05' N, 10°25' E, 1896, *G.A. Zenker* 923 (E, K, WAG); 3°05' N, 10°25' E, 1898, *G.A. Zenker* 1799 (E, K, WAG); 3°05' N, 10°25' E, 1899, *G.A. Zenker* 1925 (E, K); 3°05' N, 10°25' E, 1907, *G.A. Zenker* 3268 (E, K); 3°05' N, 10°25' E, 1907, *G.A. Zenker* 3310 (E, K); 3°05' N, 10°25' E, 1911, *G.A. Zenker* 4165 (E, K). CENTRAL AFRICAN REPUBLIC: Kongana camp, 22 km SE of Bayanga, 0.9 km from Kongana bridge on the North side of the road, 2°47' N, 16°26' E, 3 April 1996, *J. Fangounda* 506 (E); Ndakan gorilla study area, 2°21' N, 16°09' E Alt: 385m, 25 July 1988, *J.M. Fay, D.J. Harris* 8548 (E); *Fay, J.M.* 8723 (WAG); Sangha Economique Prefecture: Lindjombo, within 3 km radius of lindjombo, 2°42' N, 16°07' E Alt: 385m, 1 November 1988, *J.M. Fay, D.J. Harris* 8723 (WAG); Ndakan, gorilla study area, East bank of Sangha river from Riparian forest with *Irvingia smithii* and *Trichilia retusa*. Precip. 1400 mm, 2°23' N, 16°07' E Alt: 350m, 22 May 1988, *D.J. Harris, J.M. Fay* 730 (E); Kongana research camp, 25 km SE of Bayanga, 2°47' N, 16°25' E, 27 May 1994, *D.J. Harris* 4960 (E); W of Sangha River, 12 km NE of Bayanga, 3°01' N, 16°11' E, 13 May 2001, *D.J. Harris* 7716 (E); Bai Hoku Camp, 25 km ESE of Bayanga, 2°52' N, 16°28' E, 16 October 1995, *M. Remis* 112-95 (E); Berberati, 4°16' N, 15°47' E, *C. Tisserant s.n.* (K). CONGO: 2°10' N, 16°30' E, 10 June 2002, *D.J. Harris* 7969 (E); 12.5 km NE of Kabo, 2°07'31" N, 16°10'39" E, 1 September 2006, *G. Moukassa* 43 (E); 3 km E of Kabo (PROGEPP HQ), 2°03'14" N, 16°05'52" E, 17 August 2006, *F.O. Nzolani Silaho, J.-M. Moutsamboté & D.J. Harris* 2 (E); 2 km S of Kabo, 2°02'42" N, 16°06'22" E, 3 October 2006, *F.O. Nzolani Silaho* 393 (E). DEMOCRATIC REPUBLIC OF CONGO: Yangambi, 0°46' N, 24°27' E, 5 November 1959, *C.M. Evrard* 372 (BR, K); Yambata, 2°26' N, 22°02' E, 1914, *s. de Giorgi* 1713 (BR, K); Epulu, 1°25' N, 28°35' E Alt: 750m, 8 March 1982, *Hart, T.B.* 219 (BR, K); 1°25' N, 28°35' E Alt: 750m, 20 March 1982, *T.B. Hart* 231 (BR, K); 1°25' N, 28°35' E Alt: 750m, 5 May 1982, *T.B. Hart* 274 (BR, K); Yangambi, 0°46' N, 24°27' E, 26 June 1958, *A. Léonard* 822 (BR, K, WAG); Temena, 27 May 1937, *C. Leontowitch* 3 (BR, K); Budjala, 2°39' N, 19°42' E, 31 June 1937, *C. Leontowitch* 4 (BR, K); Yangambi, 0°46' N, 24°27' E, 1937, *J. Louis* 3606 (BR, K); 0°46' N, 24°27' E, *J. Louis* 4118 (BR, K); 0°46' N, 24°27' E, 23 April 1938, *J. Louis* 9051 (BR, K); 0°46' N, 24°27' E Alt: 470m, 26

August 1938, *J. Louis 11011* (BR, K). EQUATORIAL GUINEA: 'Bata - Utonde: Estrada kms 21–22. Area da povoacao de Ebeevang.', 13 June 1991, *M.F. de Carvalho 4730* (WAG). GABON: forestry concession Bordamur, c. 50 km NE of Mitzic, c. 1°10'18" N, 11°53'36" E Alt: 550m, 11 February 2003, *M.S.M. Sosef, C.P.C. Versteegh & B. Nziengui 2005* (WAG). GHANA. *G.K. Akpabal 928* (K); Kade A.R.S, 6°09' N, 0°55' W, 25 March 1970, *A.A. Enti 40150* (K, WAG); Atewa Range Forest Reserve, along Old Geological Survey road, c. 6°14'06" N, 0°33'00" W Alt: 400m, 26 October 1994, *C.C.H. Jongkind, H.H. Schmidt & D.K. Abbiw 1807* (WAG); Ofin Head waters reserve, 7°01' N, 1°28' W Alt: 457m, November 1934, *C. Vigne 3419* (K). GUINEA: Simandou range, W of Pic de Fon, E of Banko village, 8°31'30" N, 8°56'12" W Alt: 580m, 15 August 2008, *P.K. Haba, X.M. van der Burgt, C. Couch & A. Traore 220* (K); Nimba mountains, plot WHRS23 near Tuo, 7°35'39" N, 8°29'51" W Alt: 580m, 6 July 2008, *Nimba Botanic Team 459* (WAG). IVORY COAST: *A. Aubréville 1039* (K); 1932, *A. Aubréville 1039* (WAG); Tai Forest, 20 km S of Tai, left side of the Audrenisrou, 5°43' N, 7°24' W, 15 June 1981, *M.M. Barink 27* (WAG); F.C. de la Niégré, sud, 5°19' N, 6°11' W, 18 June 1996, *C. Chatelain, H.G. Téré 1289* (WAG); Abidjan, seeds from Tai, 13 December 1967, *F. Hallé 1298* (K, WAG); Abidjan, seeds from Tai, 30 October 1967, *F. Hallé 1298* (K); Road Sassandra to Monogaga. Rocky soil, 4°55' N, 6°20' W, 12 April 1973, *J. de Koning 1455* (WAG); About 60km North of Sassandra, left bank Davo river, East of Bayo, 5°18' N, 6°00' W Alt: 100m, 27 January 1959, *A.J.M. Leeuwenberg 2597* (K, WAG); Keibli, 5°59' N, 7°28' W, 1 June 1986, *A. de Rouw 330* (WAG); surroundings of Kodjina, 15 km south west of Abengourou, 6°39' N, 3°37' W, 28 July 1969, *C. Versteegh, R.W. den Outer 578* (WAG). NIGERIA. Sapoba, 6°06' N, 5°53' E, *s.n.* (K); Okomu forest reserve, Nikrowa rest house, 6°14' N, 5°21' E, 18 December 1927, *J.P.M. Brenan 8537* (K); Sapoba, 6°06' N, 5°53' E, 1932, *J.D. Kennedy 2326* (K); Ikom district, Afi forest reserve, near pillar fd4 on the bank of the river Nwuwuan, 6°11'54" N, 8°58'36" W, 23 May 1952, *M.G. Latilo 30995* (K); Cross river North forest reserve between miles 155 and 156, 5°34' N, 8°44' E, 11 June 1952, *M.G. Latilo 31824* (K); Oban, 5°19' N, 8°34' E, 1912, *P.A. Talbot 1729* (K).

## Discussion on persistent identifiers for cited specimens

There has been much debate concerning adoption of identifiers for specimens in biological collections (Riccardi et al. 2009; Cryer et al. 2009). Here we limit ourselves to describing our own solution, and explaining why we adopted it.

Our primary aim is enabling the author to provide a link for reader to access more information about the specimens that they are citing. The difference between linking to the original specimens used by the author, and searching for all information about a particular specimen, is an important one. Linking requires there to be a resolution mechanism that will take the reader to the original source of the data—the herbarium where the specimen is curated. Searching may return more information, but does not discriminate between the original source and other resources that (although useful) may not have been used by the author.

Linking is also an important, machine-readable way for the author to credit the sources of research materials. The links act as tags, which could be used to discover which papers cite which specimens. In future, this could also be used to build links from specimens to the papers they are cited in.

For linking to work, the identifiers used for specimens need to be resolvable via a mechanism that is widely available and stable for the foreseeable future. If there is no resolution mechanism, or the piece of software the author is using does not understand the resolution mechanism or fails, then there is no way of retrieving the original specimen data.

We started with the premise that institutions, in this case RBGE, are responsible for curating all the collections they hold, and making them available to the research community in perpetuity. RBGE has already been doing this for over three hundred years. Today this includes making information, including images and data, available on-line. Although the institution can use third party service providers it is the one ultimately responsible for maintaining consistent availability of the data on the specimens it holds. In the last three

centuries, it has not had agreements with suppliers that have lasted more than a few decades, so its implementation of any solution to the linking problem has to be as independent as possible from any single supplier, if the solution is to persist.

Resources are always limited, and so our priority is to produce a simple, easy to maintain system that will work today and for the foreseeable future. A system will only attract the level of adoption necessary, to ensure the widespread uptake that will warrant its continued maintenance and eventual migration to future technologies, if it is shown to be of value now.

We have therefore adopted the use of Linked Data (Bizer et al. 2009) compliant HTTP URIs (Hypertext Transfer Protocol Uniform Resource Identifier) as our identifier technology. These represent the standard technology used to identify resources on the World Wide Web. They can be thought of as a subset of the regular web addresses familiar from the location bar on your web browser, but importantly they follow the set of recommendations given by the World Wide Web Consortium for “Cool URIs” (Ayers and Völkel 2008). For our purposes they have four key features:

1. They hide the underlying server technology used to publish the data thus enabling us to change the way we manage and publish data without changing the identifier (i.e. they can be maintained despite technological and organisational change).
2. They carry out a process called content negotiation. This means the response from our server depends on the client who is requesting the information. Someone using a web browser will receive a web page whilst a machine harvesting metadata will receive raw data.
3. They will work on all web-connected devices currently available (e.g. desktops, laptops, tablets, eBook readers, smart phones) and likely on those to be introduced in the foreseeable future.
4. They depend for their resolution only on the existing web infrastructure currently available from multiple suppliers. We could move to a new hosting provider, a new internet service provider or a new domain name registrar. The only thing we depend on is continued legal rights to the rbge.org.uk domain name.

A major hindrance to the widespread adoption of HTTP URIs is a social one. There is a perception that, because HTTP URIs have been used to identify ephemeral resources, and broken links are often encountered whilst surfing the web, the technology must be inherently fragile. In fact, it is no more or less stable than any other identifier technology. For HTTP URIs to be resolvable to original data, the current World Wide Web infrastructure needs to be either maintained, or replaced by something that is compatible. The same applies to any other identifier technology—their resolution mechanisms need to be maintained or replaced with compatible versions. Currently, all identifier technologies use the World Wide Web and HTTP URIs as their only link to original data.

The lack of confidence in HTTP URIs is particularly important for publishers who may be reluctant to include them in publications. We hope that this paper will go some way to correcting this perception, and encourage other herbaria to adopt best practice in deploying HTTP URIs. In future, it may be worthwhile to establish a registry of stable specimen identifiers, possibly under the auspices of GBIF. We would welcome this.

Should social and technical support for the resolution of identifiers fail, all that would remain is the identifier consisting of a unique string of characters. In this case HTTP URIs provide an adequate mechanism for ensuring we are creating globally unique character strings for each of the specimens held at RBGE, so that they can be found using the search engines of the future.

## How to use our specimen identifiers

Our identifiers for herbarium specimens take the form <http://data.rbge.org.uk/herb/E00421503> where the part after the final forward slash is the barcode number which is physically on the specimen.

The two key principles in citing our identifiers are to ensure that at least the first reference to a specimen is hyperlinked and that the HTTP URI itself is visible to the reader somewhere in the document if it is printed. The way we have done it in this exemplar paper is as follows:

1. A reference to the specimen has been cited in the conventional way, as specified by the publication's guidelines, and made a hyperlink to the IH herbarium code E, using our HTTP URI as the link.
2. We have included a table that lists our HTTP URIs as the last column.
3. Whenever our HTTP URI are included where they can be seen by the reader they are hyperlinked with the URI set as the HTTP URI itself.
4. Our identifiers are always cited in full including 'http://' at the beginning.
5. The identifiers are case sensitive.
6. We have avoided including our identifiers directly in prose text, as this would have made it hard to read.

## Implementation Notes

Our implementation of this technology is very simple. We are, like many herbaria, in the fortunate position of having had a barcoding policy in place for the last 15 years, and so we have half a million databased specimens bearing unique barcode numbers, and we make data from our current collection management system available online, so that we have a herbarium catalogue with the equivalent of one webpage per specimen.

To implement the identifiers on top of this existing system, we set up a subdomain '/data' of our institutional domain name rbge.org.uk. This took a few minutes using our domain name registrar's administration panel and cost nothing. We then set up a website containing a simple script that detects whether or not a request is coming from a web browser, and then either redirects to the existing web page, or to raw data generated by second simple script. This was done on our existing web server at no additional cost. The whole identifier resolution system could be set up in less than a day by a competent web engineer, provided the prerequisites are in place. Should other herbaria wish to implement a similar solution, we would be happy to share our experience.

Our current system does not track version information. The user is presented with the current data RBGE holds on the specimen not the data held at the time any referring paper was written. Changes to information about specimens are typically additive (in the form of determination slips) and dated, so we don't see this as being of major concern. Should versioning become an issue in the future then we would continue using the same HTTP URIs as identifiers, but return multiple versions of metadata, linked together using the standard Dublin Core terms: "hasVersion"; "isVersionOf"; "replaces"; and "isReplacedBy" (DCMI Usage Board, 2012).

In the UK the Engineering and Physical Sciences Research Council (EPSRC) has created a policy framework on research data that sets out a series of expectations for how institutions should manage their data (EPSRC, 2011). Expectation number 5 refers to the use of "robust digital object identifiers" for digital objects. It seems likely to us that other funding bodies will follow EPSRC's lead, and have similar expectations of the institutions they fund. We believe that the linking mechanism proposed here can provide a simple but suitably robust mechanism for herbarium specimens.

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