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LAS Johnson Review

Botanical illustration and photography: a southern hemisphere perspective

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Abstract. To examine claims that the role of botanical art in systematic botany is diminishing because of advances in photography, this review considers relevant literature and includes a quantitative analysis of trends in modern journals, monographs and floras. Our focus is on southern hemisphere systematic botany because, relative to the northern hemisphere, this is poorly represented in modern reviews of botanical art and photography. An analysis of all digitally available papers in *Nuytsia*, the *Journal of the Adelaide Botanic Garden*, *Muelleria*, *Telopea*, *Austrobaileya* and *Systematic Botany* established that, although photographic illustrations have increased since 2000, botanical illustrations have not always diminished. The cause of these trends is unknown, but it is likely to be due to several factors, including sourcing funding for production of botanical illustration, editorial preference for the use of illustrations or photographs, author preference for either illustrations or photographs, and moving to online publication, with no charges for colour reproduction. Moreover, the inclusion of botanical artists as co-authors in some scientific publications signals an ongoing and important role. Botanical illustration brings sharp focus and meticulous attention to detail regarding form and structure of plants. Photography is useful at the macro-scale for habitat and whole-plant traits, as well as at the micro-scale for anatomical textures and ultrastructure. These complementary approaches can be important components of taxonomic discovery, with the potential for a new role in modern trait analysis in molecular phylogenies.

Additional keywords: art, botanical journal, botanical monographs, composite illustration, drawing, golden age, image, photographs, scientific illustration, trait.

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Introduction

The present review aims to assess the hypothesis that southern hemisphere botanical illustration and photography are complementary approaches to visual illustration in modern systematics. The work was stimulated by claims that the role of botanical art is diminishing in the light of advances in photography (Blunt and Stearn 1994). If this were so, a quantitative examination of the use of botanical art and photography in modern systematic journals, monographs and floras should reveal a decline. We will first define relevant terms, and summarise the use of botanical illustration and photography in southern hemisphere systematics, given that published reviews have in the main focused on northern hemisphere contributions (see Bray 1989; Blunt and Stearn 1994; Rix 2012). We discuss the role of the botanical illustrator in scientific discovery and how the discipline can continue to contribute to plant systematics, given the contemporary focus on molecular phylogenetics.

Definitions

Botanical illustration

Botanical illustration is the accurate pictorial depiction of plants and plant traits for a scientific purpose (Rix 2012), as opposed to flower painting, which has no further purpose than to be admired. 'The flower painter fails if the work lacks beauty, the botanical artist fails if the work lacks accuracy' (Stearn 1990, p. 7). However, in the best botanical illustrations, beauty is not sacrificed for truth of form (Blunt and Stearn 1994; Rix 2012; Figs 1, 2).

Camera lucida

The camera lucida is a minute truncated, half-silvered prism that allows the artist to see the superimposition of the object they are drawing onto the drawing surface. This allows the artist to draw the object in perspective, or copy or reduce it, depending on the distance of the prism from the object (Wollaston 1807). The camera lucida was invented by William Hyde Wollaston (1766–1828), who, while on a walking holiday in the Lakes District of England, was disappointed with his attempts to draw the landscape accurately; so, applying his knowledge of optics, he designed the camera lucida as a drawing aid (Hammond and Austin 1987). Although it was not commercially available until 1807, it is probable that the camera lucida was in use by botanical artists before this (Lack 2002, 2016).

Fig. 1. Botanical illustration in graphite pencil of *Chordifex abortivus* (Nees) B.G. Briggs & L.A.S. Johnson by Ellen J. Hickman in *Australian Rushes* (Meney and Pate 1999), showing the diagnostic character traits of male and female flowering culms, culm sheath, rhizome, female and male spikelets.

Photography

Photography is the science, art and practice of creating durable images by recording light or other electromagnetic radiation, either electronically, by means of an image sensor, or chemically, by means of a light-sensitive material such as photographic film (Spencer 1973; Fig. 3). The etymology of the word 'photography' is from Greek roots of 'photo' meaning 'light' and 'graphe' meaning 'drawing', together meaning 'drawing with light' (D. Harper, Online Etymology Dictionary, 'photography (n.)',

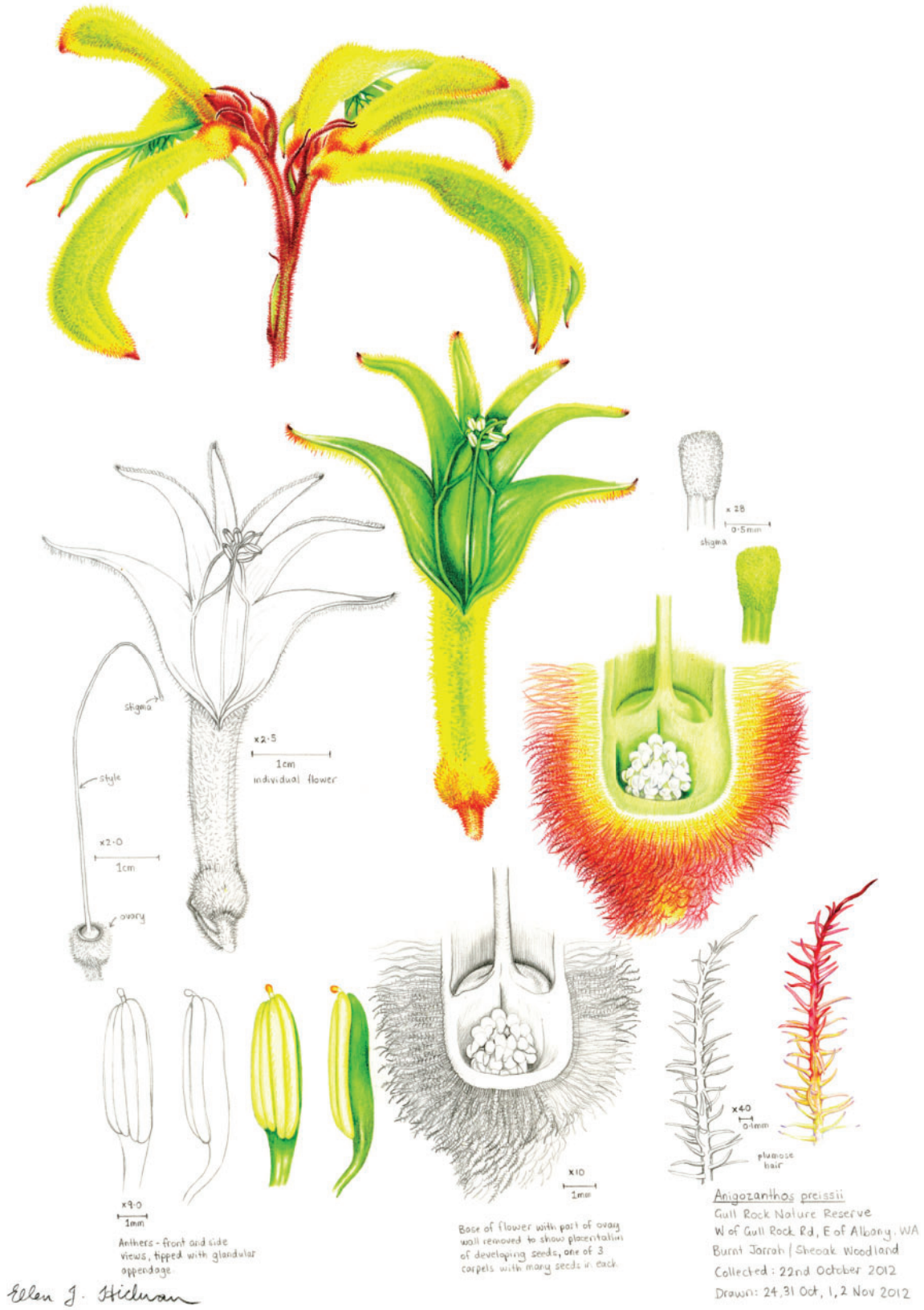

Fig. 2. Botanical illustration study in pencil and aquarelle by Ellen J. Hickman of the flower traits of *Anigozanthos preissii* Endl.: inflorescence, flower, ovary and style, section through ovary, stigma detail, anther with glandular appendage and plumose hair.

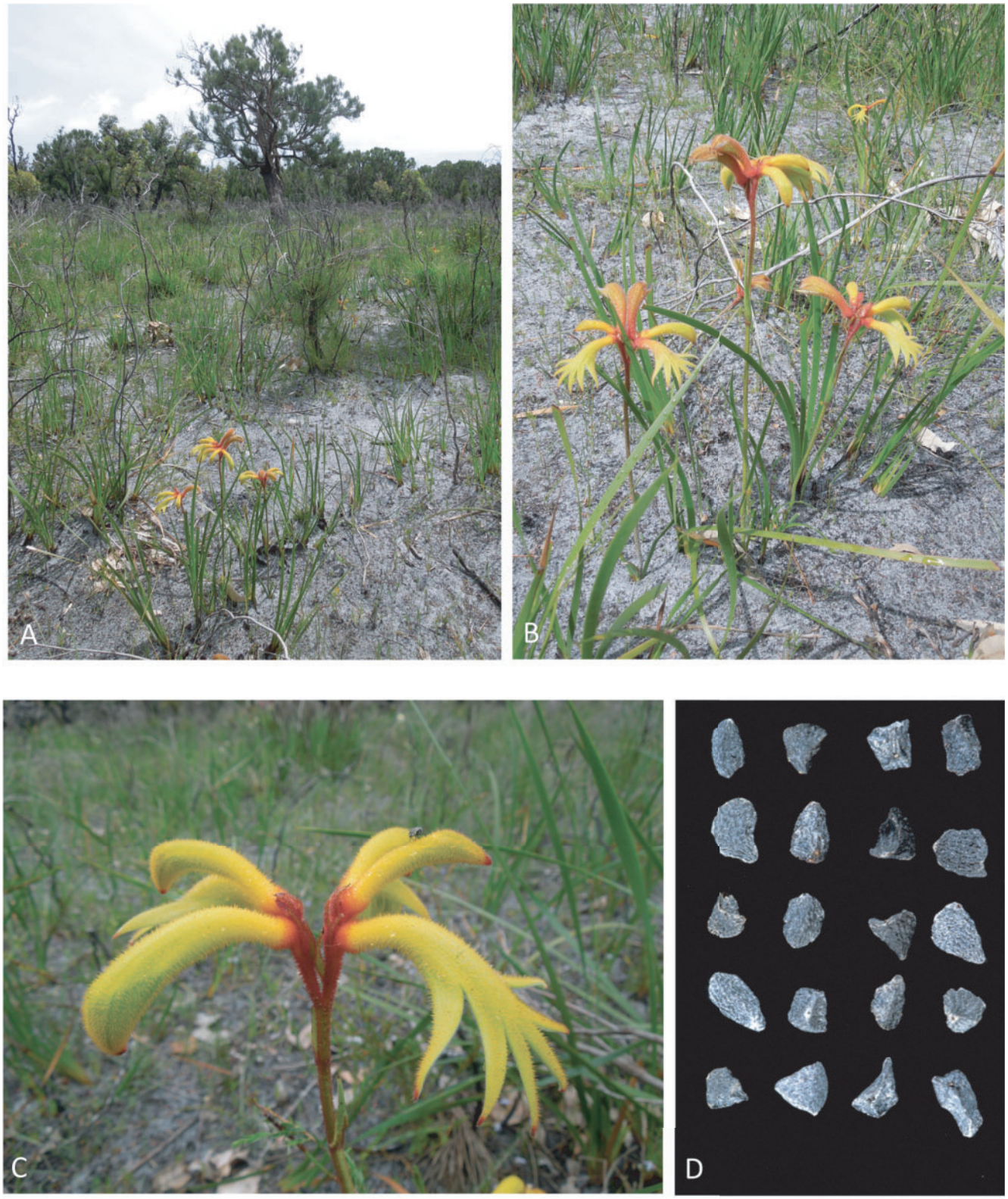

Fig. 3. Photographs of *Anigozanthos preissii* Endl. A. Habitat: recently burnt jarrah and sheoak woodland, Gull Rock Nature Reserve, Western Australia. B. Whole plants. C. Inflorescence. D. Seeds. Photos: Ellen Hickman (A–C), Luke Sweedman (D).

see http://www.etymonline.com/?term=photograph, accessed 24 May 2016). The birth of practical photography is generally accepted as 1839 (Hirsch 2008). The development of the camera has its roots in antiquity, with the discovery of the principles of the camera obscura (Latin for dark room).

Trait

A trait is defined as 'a distinguishing quality or characteristic' and 'a genetically determined characteristic' (Farlex, The Free Dictionary, see http://www.thefreedictionary.com/trait, accessed 18 May 2015). In biological terms, *Henderson's Dictionary of Biology* stated that a trait is 'a distinct phenotypic character which may be either heritable or environmentally determined or both.' (Henderson and Lawrence 2005, p. 667). A trait is the expression of genes in an observable way. For example, eye colour is a character, whereas the different expressions of that colour such as blue, brown and hazel are traits. The etymology of the word is from the Middle French appearing *c.* 1470–1480, in the transition period between Old French and Modern French. It comes from the Latin *tractus*, which means drawing, as in pulling a chariot (from *trahere* to drag), or as in drawing out of space and time, or drawing a line, such as a track or a tract of country. In French, trait came to have many meanings, one of which is 'a particular feature of mind or character'. This definition was brought into usage in English. Pertinent to the artistic aspect of the present review, an early meaning from the French is 'the stroke of a pen or pencil in a picture' (Farlex, see http://www.thefreedictionary.com/trait).

Historical use of botanical illustration in southern hemisphere systematics

Illustrations of plants have been a medium for identification, analysis and classification for centuries, serving physicians, pharmacists, botanical scientists, taxonomists, plant collectors, gardeners, designers and amateur enthusiasts of natural history (Saunders 2009). Prior to photography, the botanical illustration was the only way of recording visually what a plant looked like. Botanical illustration became increasingly important during the Enlightenment and the subsequent age of botanical exploration when colonial powers and entrepreneurs funded voyages of discovery and scientists needed artists who could faithfully record the character and traits of species' collections while they were fresh.

The history of botanical illustration has been well documented elsewhere (Blunt and Stearn 1994; Rix 2012). These treatments suggest that botanical illustration has mostly developed in parallel with artistic trends of the time, as well as maintaining pace with the advances in the technology of both printing and photography (Simpson and Barnes 2008). The style of the illustrations started with realistic depictions of the plants portrayed in the first century when their importance was to illustrate monastic herbals. For the next 1000 years, the illustrations of these herbals degenerated through repeated copying, with little reference to live plant material. This led to stylisation to the point that the illustrations became nothing more than decorative embellishment to the text (Blunt and Stearn 1994). Examples illustrating this were the *Pseudo-Apuleius Herbarius* by the fourth century author Pseudo Apuleius (Paul K, 'Peacay', see http://bibliodyssey.blogspot.com.au/2007/01/pseudo-apuleius-herbarium.html, accessed 24 July 2017; Jeremy Norman & Co., see http://www.historyofinformation.com/expanded.php?id=2580, accessed 24 July 2017), illustrations in the 13th century *Codex Vindobonensis 93* (Wikipedia, *Pseudo Apuleius*, see https://en.wikipedia.org/wiki/Pseudo-Apuleius, accessed 24 July 2017), the woodcut illustrations of the copy of *Pseudo-Apuleuis* printed in Rome in *c.* 1480 (Ivins 1944), and the woodcut illustrations of one of the earliest English herbals, *Grete Herball* (Treveris 1526; Sims 2013).

The Renaissance brought the rebirth of Naturalism back to botanical illustration, with significant artists of the time such as Leonardo da Vinci (1452–1519) and Albrecht Dürer (1471–1528) making important contributions. These Renaissance illustrations were forerunners to the golden age of botanical illustration, in the hundred or so years from 1750 to 1850, prompted by Linnaeus's contribution to systematic science (Linnaeus 1737). The Bauer brothers were prime examples of practitioners at this time. Franz (1758–1840) and Ferdinand (1760–1826) Bauer were, in the opinion of many, the greatest botanical artists of all time (Green 1977; Mabberley 1999, Lack 2016). From the end of the 18th century and into the 19th century, this legacy continued with adventurous Victorian-era artists, such as Marianne North (1830–1890) from England, visiting the new colonies of the expanding Empire, discovering new species, bringing home specimens and making detailed drawings. This time also saw the publication of illustrated botanical journals such as *Curtis's Botanical Magazine* (Royal Botanic Gardens Kew, see http://www.kew.org/science-conservation/research-data/publications/curtiss-botanical-magazine, accessed 24 May 2016), as a result, in part, of the flood of new plants coming in from abroad and voracious appetites for novelties in horticulture.

Below is a brief summary of the history of botanical illustration in the southern hemisphere, with examples from South Africa, Australia and South America.

South Africa

Botanical art in South Africa is well illustrated in several botanical books (Rix 1980; Arnold 2001). Images produced of southern African flora, during the 143 years following settlement by the Dutch in 1652, often failed to acknowledge the artists (Rourke 2001). In the 1800s, when the British colonised South Africa, women began to emerge as competent artists. Many, on brief stays in South Africa, were captivated by its flora. Husband and wife, John (1792–1871) and Margaret (1810–1884) Herschel, teamed-up during their 4 years at the Cape (1834–1838) to produce accurate renditions of native flora. John Herschel used a camera lucida to produce the outlines and Margaret painted in the details (Rourke 2001).

South Africa has a large diversity of succulents, which do not preserve well as dry specimens, and, as a consequence, have been poorly represented in herbaria. To provide essential taxonomic information about these succulent species, dried specimens need to be complemented by illustrations, particularly of stone plants (*Lithops* N.E.Br spp.), bokbaaivygies (*Dorotheanthus bellidiformis* (Burm.f.) N.E.Br.) and sour figs (*Carpobrotus edulis* (L.) N.E.Br; Arnold 2001). Francis Masson

(1741–1805), Scottish botanist and the first plant hunter of Kew, produced a significant collection and body of illustrations of South African succulents during his expedition to South Africa from 1772 to 1775 (Masson 1776).

The first solely South African-produced botanical publication was *Natal Plants* (Wood and Evans 1898), published from 1898 to 1912. Then Rudolf Marloth's *Flora of South Africa* was issued in four volumes from 1913 to 1932 (Marloth 1932). The major publication of South African botanical illustrations was *(The) Flowering Plants of (South) Africa* (1921–2015; SANBI, see http://biodiversityadvisor.sanbi.org/literature/4327-2/flowering-plants-of-africa/, accessed 23 July 2016). It was modelled on *Curtis's Botanical Magazine*, but was unique in its geographical focus on Africa and primarily southern African plants. In each volume *(The) Flowering Plants of (South) Africa* described 40 species, each with a full colour plate. In initial volumes, the illustrations were hand-coloured lithographs (Pole Evans 1921). Modern volumes combine full-colour illustrations, line drawings of dissections and colour photographs (Grobler 2015).

After the Second World War, with advances in colour printing, many publications feature works of botanical artists, including Mary Page (1867–1925), Cythna Letty (1895–1985) and Auriol Batten (1918–2015), whose works appeared in *Flowers of Southern Africa* (Batten 1988) and *Dierama*, *the Hairbells of Africa* (Hilliard and Burtt 1991). Ellaphie Ward-Hilhorst (1920–1994) illustrated the *Revision of the Genus Haemanthus* (Snijman 1984). Fay Anderson (1931–present) contributed artwork to the *Proteas of Southern Africa* (Rourke 1980), *The Moraeas of Southern Africa* (Goldblatt 1986) and *The Genus Watsonia* (Goldblatt 1989).

The wealth of well-illustrated botanical publications to emerge from South Africa was attributed by Rix (1980) to its uniquely rich native flora and the wealth produced from the mining of its natural resources of gold and diamonds. Rourke (2001) agreed that these were valid reasons, but suggested that this wealth of well-illustrated botanical publications was also underpinned by a strong scientific-investigative ethos. There were not many countries where these three things converged; South Africa was one, and Australia was another.

Australia

Illustration of the diverse and rich Australian flora was well reviewed by Hewson (1999). William Dampier (1651–1715) was not a botanical illustrator, but botanical drawings, believed to be made by his clerk, James Brand, were published in Dampier's *A Voyage to New Holland* in 1703, the account of the *HMS Roebuck's* expedition to Australia in 1699. These were the first known illustrations of Australian plant species (Hewson 1999). One of the best plates for contemporary identifications includes illustrations of *Conostylis stylidioides* F.Muell., *Sida calyxhymenia* DC., *Diplolaena grandiflora* Desf. and *Beaufortia sprengelioides* (DC.) Craven.

Sydney Parkinson (1745–1771) was accompanying natural-history artist on Captain (then Lieutenant) James Cook's (1728–1779) first voyage to circumnavigate the world in the *Endeavour*. A total of 412 of Parkinson's illustrations, both botanical and zoological, were of Australian species. Because of the pressure to record as much as possible, Parkinson produced only three finished watercolours during the voyage. The remainder of his illustrations were unfinished pencil drawings, with or without parts coloured, or annotation about colour (Lack 2002). Botanist Joseph Banks (1743–1820) wrote in his diary that, in a 14-day period, Parkinson produced 94 drawings, and the crew noted that Parkinson 'frequently sat up all night drawing' (Blunt 1983).

Probably the earliest most recognisable illustrator of Australian plants was Ferdinand Bauer (1790–1826). Numerous books and articles have been published on his life and working practice (Lhotsky 1839, 1843; Stearn 1960; Lack 1997, 2016; Watts *et al.* 1997; Mabberley 1999). He was appointed the natural-history illustrator on Matthew Flinders' (1774–1814) *Investigator* expedition in 1801 to circumnavigate Australia. Bauer overcame the challenge of the damp conditions on the ship, which resulted in his paper going mouldy and being unable to accept watercolour pigment, by executing pencil sketches of the specimens collected, and using a number coding system to record the various colours. He used this technique as a guide for painting the final watercolours at a later stage.

Bauer was most renowned for his attention to detail, particularly the exquisite dissections of various aspects of the flowers and fruits of the species he illustrated. He was also held in high esteem because of the amount of work he was able to execute during the expedition. In all, Bauer executed 1542 Australian plant sketches, 180 Norfolk Island plant sketches and over 300 animal sketches. Bauer published some of his artwork in *Illustrationes Florae Novae Hollandiae* (Bauer 1813). This publication was not a financial success for Bauer, largely because of his perfectionism. He could not find anyone capable of either engraving or colouring the plates to his satisfaction, so he was obliged to execute every part of these works in his own hand, occupying considerable time.

Lack (2002) proposed that as far back as the early 1800s, a camera lucida was used by Ferdinand Bauer to achieve the exceptional number and quality of illustrations that he produced on the *Investigator* expedition. Lack (1998) suggested that this was probable for several reasons, including the following: (1) Wollaston, the inventor of the camera lucida, knew Sir Joseph Banks; (2) Banks employed Bauer as natural-history draughtsman for the *Investigator* expedition; (3) the *Investigator* expedition was supplied with all the latest instruments; (4) Bauer's pencil drawings were highly accurate and in a very firm continuous line; (5) the camera lucida can be easily combined with a magnifying lens or microscope to produce the detailed dissections Bauer was renowned for; and (6) Bauer achieved a significant quantity of pencil drawings during the arduous expedition. In addition, Nicephore Niepce (1765–1833), the inventor of the first photograph from nature, was in contact with Ferdinand's brother Franz, and gave Franz this photograph. This, along with numerous optical instruments auctioned after Franz's death, demonstrates that the Bauers were interested in the latest development in optics, which led to the universal praise for their accuracy (Lack 2002).

In the 1820s, Allan Cunningham (1791–1839) continued the Banksian tradition as an overseas collector for Kew Gardens, sending back seeds and herbarium specimens from Australia (as well as Brazil and New Zealand; Mabberley 2000). William Townsend Aiton (1766–1849), then curator of the gardens, had

Allan's brother, Richard Cunningham (1793–1835), prepare manuscripts for the *Hortus Kewensis* (five volumes 1810–1813) and employed two artistically talented gardeners, Thomas Duncanson (fl. 1820s) and George Bond (1806–1892), to make watercolour drawings of the plants newly raised from this seed. Between them, they prepared ~2000 watercolours, which were kept in folios, indexed by Richard Cunningham. None of the watercolours was published. Some illustrations were sent to William Jackson Hooker (1785–1865), then Professor of Botany at Glasgow University, to be published in the *Botanical Magazine*. Hooker redrew these illustrations, so none of them bears the original artist's name. The folios have since been cut up, and the watercolours inserted in the systematic drawings collection housed in cupboards of the Herbarium at Kew (Mabberley 2000).

Marianne North (1830–90) was a remarkable Victorian painter and traveller, who visited Australia at the behest of Charles Darwin (1809–82), and was captivated by its plants and landscapes. She initially accompanied her father and then, following his death, went on her own, at a time when few women travelled alone, to scour the world for spectacular plants to paint in oils (Ponsonby 1996). A feature of North's work was that the subjects were painted within their natural environment. The inclusion of landscape in the works communicates more about the distant and exotic parts of the world than if only the plant was depicted (Hewson 1999), and puts the subjects in context with place. Scientists consider North primarily an artist, although she discovered and portrayed species new to science (*Nepenthes northiana* Hook f., *Kniphofia northiae* Baker and *Northia seychellana* Hook f.; Blunt and Stearn 1994). She presented her life's work to the UK and purpose-built a museum and gallery at Kew Gardens to house it. The museum opened to the public in 1882, with 832 paintings covering its walls from floor to ceiling (Ponsonby 1996).

One of the first resident, published, botanical illustrators of Australia was Thomas Watling (1762–1814), a convict and artist who had been transported to the penal colony for forgery (Hewson 1999). Watling's paintings were used by James Sowerby and James Smith in the publication of Australian's first flora, *A Specimen of the Botany of New Holland* (Smith 1793).

Another prominent resident, who now has an annually presented international award (the Margaret Flockton Award) in her honour, was Margaret Lilian Flockton (1861–1953). She was employed as a botanical illustrator at the Royal Botanic Gardens, Sydney, for 27 years (1901–27), and in collaboration with the then director, Joseph Henry Maiden (1859–1925), produced thousands of high-quality botanical illustrations, which are represented in publications such as *The Forest Flora of New South Wales* (Maiden 1904, 1907, 1908*a*, 1908*b*, 1913, 1917*a*, 1922*a*, 1923) and *A Critical Revision of the Genus Eucalyptus* (Maiden 1909, 1914, 1917*b*, 1920, 1922*b*, 1924, 1929, 1933).

Professional training for botanical illustrators in Australia was generally unavailable until the latter decades of the 20th century, when there was an explosion in the number of botanical artists practising in Australia (Hewson 1999). These artists were either trained through art colleges, self-taught, or were scientists putting their own artistic skill into practice. Several important botanical artists from the State of Victoria, including Celia Rosser (1930–present), Terrence Nolan (1934–present) and Anita Barley (1955–present), owe their apprenticeship to training at the Royal Melbourne Institute of Technology. Queensland artist Margaret Saul (1951–present) trained at the Brisbane School of Art. The South Australian Herbarium botanical illustrator, Ludwik Dutkiewicz (1921–2008), trained at the Lwow School of Art in Poland before emigrating to Australia. In 1978, the University of Newcastle began a course in wildlife illustration, which included training in botanical illustration; Nicola Oram (1966–present) was one of its graduates. However, the majority of their graduates found careers outside the science sphere. Private training schools and master classes also developed in some of the capital cities. These were usually run by practicing botanical artists, such as the Botanical Art School of Melbourne run by Jennifer Phillips (1949–present). This enterprise provided an extra form of income to the teaching artist, in a vocation that is difficult to make a full-time living, and had a positive influence on the standard and quality of work produced in that State (Hewson 1999).

Self-taught artists who have made considerable contributions to plant systematic science include Stanley Kelly, Rica Erickson and Margaret Menadue. Stan Kelly (1911–2001) was an engine-driver from Victoria, who devoted 41 years to painting the books titled *Eucalyptus*, with the 1st edition (Kelly 1969) containing 250 colour illustrations and the 2nd edition (Kelly *et al.* 1977) 53 more. Rica Erickson (1908–2009) was a teacher, historian, amateur botanist and artist whose descriptive work, recognised and used by scientists, includes *Orchids of the West* (Erickson 1951), *Triggerplants* (Erickson 1958), *Plants of Prey* (Erickson 1968) and historical works such as *The Drummonds of Hawthornden* (Erickson 1969). Margaret Menadue (1942–present) illustrated the *Flora of the Perth Region* (Marchant *et al*. 1987) and contributed to the *Flora of Australia* (Wilson 1984).

Scientists illustrating their own work often did this by default because of lack of funds. Winifred Curtis (1905–2005) illustrated *The Students' Flora of Tasmania* (Curtis 1963). Nancy Burbidge (1912–1977) illustrated the *Flora of the Australian Capital Territory* (Burbidge and Gray 1970). Helen Aston (1956–1991), botanist at the National Herbarium of Victoria, illustrated her work *Aquatic Plants of Australia* (Aston 1973). Bruce Maslin (1946–present), botanist at the Western Australian Herbarium, illustrated *Acacia* in volumes of *Nuytsia* (Maslin 1983).

Australian botanical artists have also united in some States to form societies. The Botanical Artist Group of Western Australia, more affectionately referred to by the acronym BAGs, was formed in 1991 for mutual support, but it also raised awareness of the subjects and the working methods of members through exhibitions and publications. Rica Erickson was a founding member of the group, following the exhibition *Wildflowers in Art* at the Art Gallery of Western Australia (Gooding 1991). Current members include Patricia Dundas (1952–present), Ellen Hickman (1968–present), Penelope Leech (1947–present), Philippa Nikulinsky (1942–present), Margaret Pieroni (1936–present) and Katrina Syme (1947–present). Their work in plant systematics has been as

individuals, rather than as a group, with each member having a particular passion, *viz*. Patricia Dundas, orchids (Brown *et al.* 2008) and eucalypts (S. D. Hopper, unpubl. data); Ellen Hickman, Restionaceae (Meney and Pate 1999; Fig. 1) and Haemodoraceae (Hopper 2003; Fig. 2); Penelope Leech, eucalypts (S. D. Hopper, unpubl. data); Margaret Pieroni, dryandras (Cavanagh and Pieroni 2006) and *Verticordia* DC. (George and Pieroni 2002); Philippa Nikulinsky, *Lechenaultia* R.Br. and desert plants (Nikulinsky and Hopper 2005); and Katrina Syme, fungi (Bougher and Syme 1998). As a group, the BAGs exhibited annually at the Western Australian Wildflower Festival at Kings Park from 1992 to 2003. They also combined their talents to produce illustrations of each State and Territory's floral emblem for commemorative coins produced by the Perth Mint. The artwork of the BAGs was celebrated in the book *Brush with Gondwana* (Gooding 2008), which documents the diversity of styles and activities of each member in investigating and celebrating the globally renowned flora of Western Australia.

South America

During the 17th and 18th centuries, South America was the dominion of the Spanish and Portuguese, who overwhelmingly had little interest in its natural history and actively discouraged exploration by foreigners (Rix 2012). The French priest, Louis Feuillée (1660–1732), visited Chile and Peru in 1707 and published his observations, including 100 of his own drawings of the plants in *Journal des Observations Physiques, Mathématiques et Botaniques* (Rix 2012). In the late 18th century, several expeditions initiated by King Carlos III of Spain were conducted to study the flora of South America. The following four famous botanists dominated this period: Jose Celestino Mutis (1732–1808), Don Hipolito Ruiz Lopez (1754–1816), Don Jose Pavon Jimenez (1754–1840) and Joseph Dombey (1742–1794).

Pilar de San Pío Aladrén and Mostazo Fernández gave an account of Mutis in the catalogue for an exhibition of old and new South American Botanical art held in 2009 (Pilar de San Pío Aladrén and Sherwood 2010). Mutis was medically trained but was also interested in natural history. Mutis sent several unsuccessful petitions to the King in Madrid to obtain permission to set up a botanical institute and fund an expedition to collect material for it. However, in 1783, with the help of the new Archbishop-viceroy, an expedition was organised to explore New Granada (now Colombia) and record the plants pictorially, noting their medicinal, horticultural and agricultural value. Mutis believed that drawing was a crucial part of the naturalist's work, so he established schools for illustrators, in Mariquita and in Santa Fe de Bogotá, where plants from the expedition were recorded. The artists were local men with no formal training. The institute operated until 1816 and trained 40 botanical artists. The artworks have a particular formal style, somewhat flat as if the specimens are laid out for pressing (e.g. *Mutisia clematis* L.f., named in honour of Mutis; Rix 2012). The expedition collected ~2700 species, which constitute only a small proportion of Colombia's rich flora.

The technique used to produce the artworks was painting in tempera on paper. Mutis prepared the colours himself, using pigments extracted from local plants and minerals, which he mixed with oils, gum, ammonia and other solvents. Usually, three drawings were made of each specimen, including two in ink (black and sepia), which were used as models for the engravings, and a third was made in tempera, which was the definitive study. The collection of 5607 plates (3086 in tempera, 1325 in sepia, 1139 in black ink and 30 pencil drawings) are now housed in the Real Jardín Botánico, Madrid. These artworks have preserved to this day because of Mutis' insistence on using high-quality paper. There are also 500 descriptions of plants, far fewer than the number of plates, because Mutis gave priority to the drawings over the written word, considering the former provided sufficient explanation. Publication of the works did not occur until over a century later. Since 1954, the artworks have been successively reproduced in a collection of volumes entitled *Flora de la Real Expedición Botánica del Nuevo Reino de Granada* (Flora of the Royal Botanical Expedition to the New Kingdom of Granada; Pérez Arbeláez and Mutis 1954).

Ruiz, Pavón and Dombey, with accompanying artist Isidor Galvez, explored Peru, Chile and parts of Ecuador, Bolivia and Colombia from 1777 to 1788. The results were first published in *Prodromus* in 1794, with 37 engraving after Galvez's drawings, and later in *Flora Peruviana, et Chilensis*, with 365 engravings (Ruiz and Pavón 1794).

Another important contributor at this time was the polymath Prussian, Friedrich Wilhelm Heinrich Alexander Freiherr von Humbolt (1769–1859), who made a thorough study of tropical South and central America from 1799 to 1804, in the company of French botanist Aimée Bonpland (1773–1858). Their extraordinary expedition took them from the Orinoco and Rio Negro, to visit Mutis and climb Mount Chimborazo in Ecuador, down the coast of Peru and back to France through Mexico and North America. The results of the expedition were written up in *Le Voyage aux Regions Equinocxiales du Nouveau Continent*. Part 6 contains the plants in 15 volumes. The illustrations by Poiteau and Turpin were drawn from dried specimens, making them scientifically accurate but rather sterile (Rix 2012).

From 1817 to 1821, Carl Friedrich Philipp von Martius (1794–1868) travelled across Brazil, accompanied by zoologist Johann Baptist von Spix (1721–1826), and collected several thousand plant specimens. On his return to Munich, he published two substantial works, namely, *Historia Naturalis Palmarum* with 240 chromolithographs based on his own drawings, and *Flora Brasiliensis* with 4000 lithographs and some nature prints of the plants he collected (Rix 2012).

The most important driving force in botanical art in South America in the 20th century was Margaret Mee (*nee* Brown 1909–1988; Pilar de San Pío Aladrén and Sherwood 2010). Starting in her mid-40s, she devoted years to painting the plants of the vanishing Amazonian rainforest in a living state. She portrayed orchids and bromeliads, which have characters that are often difficult to preserve in dry herbarium specimens. Her published works include *Flowers of the Brazilian Forests* (Mee 1968), *Flores do Amazonas Flowers of the Amazon* (Mee 1980) and *In Search of the Flowers of the Amazon Forests* (Mee 1988). Her work contributed to global awareness of what was being lost in the Amazon through mining and logging. On her death, a group of scientists and friends created the Margaret Mee Foundation (MMF) to help send a promising Brazilian

botanical artist to the Royal Botanic Gardens, Kew, to work with the resident Kew artist, Christabel King, and then return to Brazil to inspire others.

Since 1989, the MMF has supported an artist each year (except 2008 and 2010–2014), making a total of 21 artists that have returned to Brazil to continue Mee's work (K. Terrell, *Botanical Art & Artists – Contemporary Botanical Artists in Middle and South America*, see http://www.botanicalartandartists.com/botanical-artists-in-south-america.html, accessed 21 May 2016). But the MMF is not the only source of contemporary botanical artists in South America. The Demonte family, made up of the late Étienne (1931–2004), his two sisters Rosalia (1932–2009) and Yvonne (1932–present) and his two sons André (1957–present) and Rodrigo (1961–present), and Rosalia's daughter Ludmyla, are producing a dynasty of Brazilian botanical artists that seek to inspire conservation through their artistic output (Pilar de San Pío Aladrén and Sherwood 2010). Patricia Villela (1952–present), initially trained at the School of Visual Arts in Rio in the 1970s, began her botanical art career in the 1990s. She concentrates on bromeliads and heliconias, liaising with the Rio de Janeiro Botanical Gardens (see http://www.botanicalartandartists.com/botanical-artists-in-south-america.html, accessed 21 May 2016). Alvaró Evando Xavier Nunes (1945–present) initially qualified and worked as an architect. He started to study botany in 1989, particularly in the Brazilian savanna, and has painted many of the fruits of native trees from Amazonia and the Pantanal. He spends long periods working in remote areas that have received little botanical attention. His drawings have been published in several books, including *Fruiteras da Amazonia* (Fruit Trees from the Amazon), and a series of books published by Embrapa, the Brazilian Institute for Rural Research (Sherwood 2001).

Use of photography

As the focus of this review is on botanical illustration, and modern systematic botanists are familiar with the common use of photographs in their published work, we address photography here only to the extent of general techniques and contemporary use.

Photographic techniques have been used to create botanical illustrations, as well as for visual aids of botanical artists, since the early 1800s (Simpson and Barnes 2008). The first book produced entirely by photographic means, which predates the camera, was a botanical work of cyanotypes (blue prints) depicting seaweeds (Atkins 1843). Although these images lacked three-dimensional form and colour, the technique produced clear outlines of the object shape and details of structures such as veins.

Camera technology has developed from the camera obscura, to Daguerreotypes, single-lens reflex (SLR) cameras, to the introduction of modern digital cameras in the 1990s, and photographs have developed from monochrome images that require hand-colouring to full-colour reproductions (Simpson and Barnes 2008).

Contemporary digital imaging has broadened the possibilities of visually representing botanical specimens. A very quick method was scanning an arrangement of plant parts on a flatbed scanner (Metzing 2004; Koltnow 2005; Dorrat-Haaksma and Linder 2012), but this was limited by the flatbed scanner dimensions. The arrival of high-quality SLR cameras allowed for greater versatility in the production of photographic images of both large and small aspects of plant morphology (Lüth and Frahm 2011; Barrett and Wilson 2012).

Photographic images of plants have often been of limited use for illustrating plant components because of the lack of the focal depth of the photograph, particularly those taken through the light microscope. However, in recent years, image-stacking software, that can blend a series of digital images (McCormack 2006), allows the photographer to emulate the infinite depth of focus achieved by the botanical artist (e.g. Breeden and Breeden 2010).

Many botanical works, particularly field guides, were illustrated solely or mainly by photographs. Examples of Australian publications include the following: *Field Guide to the Eucalypts* (Brooker and Kleinig 1990); *A Field Guide to the Eremophilas of Western Australia* (Brown and Buirchell 2011); and *Identification and Ecology of South-west Australian Orchids* (Brundrett 2016). Examples of New Zealand publications include *New Zealand Ferns and Allied Plants* (Brownsey and Smith-Dodsworth 2000), *An Illustrated Guide to New Zealand Hebes* (Bayly and Kellow 2006) and *New Zealand's Native Trees* (Dawson and Lucas 2011). Examples of South African publications include *A Field Guide to Wildflowers Kwazulu–Natal and the Eastern Region* (Pooley 1998), *Field Guide to Fynbos* (Manning 2007) and *Restios of the Fynbos* (Dorrat-Haaksma and Linder 2012). Examples of publications for the South American flora include *Seeds of Amazonian Plants (Princeton Field Guides*; Cornejo and Janovec 2010) and *A Field Guide to the Families and Genera of Woody Plants of North-west South America (Colombia, Ecuador, Peru) with Supplementary Notes on Herbaceous Taxa* (Gentry 1996).

Microscopy produced magnified visual or photographic images of objects too small to be seen with the naked eye. Two well known branches of microscopy used in botanical science are optical and electron microscopy, and their use depends on the resolution required.

Optical or light microscopy involves passing visible light transmitted through or reflected from the sample through a single or multiple lenses, to allow a magnified view of the sample. The resulting image can be detected directly by the eye, imaged on a photographic plate or captured digitally. The most recent development was the digital microscope, which used a charge-coupled device (CCD) camera to focus on the specimen of interest, and showed the resulting image on a computer screen.

Until the invention of subdiffraction microscopy, the wavelength of the light limited the resolution of traditional microscopy to ~0.2 μm. So as to gain higher resolution, an electron beam with a far smaller wavelength was used in electron microscopes. Transmission electron microscopy (TEM) was similar to the compound light microscope by sending an electron beam through a very thin slice of the specimen. The resolution limit was ~0.05 nm. Scanning electron microscopy (SEM) visualised details on the surfaces of specimens and gave a three-dimensional view. It gave a resolution of ~0.4 nm. Microscopy has allowed the visualisation of micro- and ultra-structures such as cell structure, anatomical sections and surface textures.

Prior to photography, botanical illustrations were the only way of recording visually what a plant looks like. The senior author of the present paper is often asked why bother drawing a plant when you can just take a photograph of it? Although photographs may seem an alternative form of illustration, there are some problems with using photographs to depict plant structures. Photographs are not good at providing clear depth cues, and artists can eliminate or underplay extraneous traits, while clearly portraying the essential ones. Furthermore, research has revealed that human vision and cameras work very differently. Cameras treat each piece of information the same, whereas illustrators emphasise boundaries and the outline of objects. Simplifying the detail to show just the essential elements of the subject being described creates a satisfying and understandable image for the human eye (Flannery 2013).

The camera has become a useful addition to the artist's tool kit (Blunt and Stearn 1994). Cameras are used to record a quick reference image for colour, but serve as a guide only, because the resulting photographic images are rarely true. Photographs are more often used to visually describe the habitat (Fig. 3A), or micrographs of the surfaces of structures such as seeds or pollen (Fig. 3D). Simpson and Barnes (2008) discussed the compilation of a composite illustration of photographic images and suggested that this could be used more readily than it has been in the past. However, the method required to compose a composite illustration of photographic images requires as much time and expertise as the compilation of a composite illustration composed of hand-drawn and painted botanical illustrations.

Challenge of colour

Any discussion of the role of botanical illustration and photography in plant systematics must consider colour and the capacity of each image type to accurately portray traits and characters. Colour illustrations of plants are icons of natural-history illustration (Nickelsen 2006). Botanical illustrations have always been expensive to produce (Flannery 2013). Contemporary botanical illustrations are most often made in black and white with pen and ink. Half-tone drawings are used to give more indication of mass, but colour is rarely used, because of the economics of time and the cost of production, as well as the challenge of being able to reproduce those colours accurately before the specimen deteriorates.

Carl Linnaeus (1707–1778) wrote in *Philosophia Botanica*, his 1751 theoretical treatise on the taxonomy of plants that 'colour is remarkably changeable, and so is of no value in definitions' (Nickelsen 2006, p. 3). Linnaeus explicitly excluded colours from the qualities that he considered eligible for characterising species, not just because the colours of plants may vary depending on the plant location, but also because it was impossible to guarantee consistent definition of colour, not even in illustrations.

At least three strategies to record the colour of plant specimens being illustrated in the 18th century seem to have been employed, including (1) describing the colours in technical terms, i.e. words, (2) colouring small portions of the sketches of various parts, i.e. reference sketches and (3) describing colour in abbreviated code, such as numbers and sometimes letters that refer to a colour chart (Lack and Ibáñez 1997).

The use of a code was practiced as far back as Albrecht Dürer's day (Koreny 1989). The most proficient proponents of a colour chart were the Bauer brothers. They started using a colour chart under the tutelage of Dr Norbert Boccius (1729–1806) and Nikolaus Joseph von Jacquin (1727–1817). It was unclear whether the brothers used a standard technique employed by illustrators in Vienna at the time or whether they invented their own (Lack and Ibáñez 1997). Their initial colour chart consisted of 140 numbered colours. This colour chart is preserved today in the Real Jardin Botanico in Madrid. Ferdinand Bauer went on to develop a colour chart of 250 shades used for drawings in John Sibthorp's (1758–1796) *Flora Graeca* (Sibthorp and Smith 1806, 1813, 1819, 1823, 1825, 1828, 1830; Sibthorp and Lindley 1833, 1837, 1840). Then, for his Pacific work, Bauer devised a system of almost a thousand shades of colour, with associated letters and cryptic abbreviated German and English words to designate texture and shininess (Mabberley *et al.* 2007).

Most botanical illustrations from the mid-eighteenth century to early nineteenth century were published as hand-coloured engravings. This confronted botanists, and their employees, with considerable practical and methodological challenges. Employing enough colourists, with experience and skill, added considerably to the cost of production and required supervision to maintain consistency. Ready-made colours were impossible to find, so the colours had to be hand-mixed from toxic pigments, which required careful guidance or years of experience, and there was a lack of standardisation in colour recipes, colour names and in the way they were used and referred to. There were examples of published colour recipes, but they often lacked detail, so probably most workshops found their own solutions to these technical problems, leading to different names being used for the same pigments and colour mixes (Nickelsen 2006).

Contemporary coloured botanical illustrations are rendered in either oil paints or watercolour paints, and, more rarely, coloured pencil. Both paint media have pigment suspended in a binding medium. For oil paints, the binder is usually linseed oil. For watercolour paints, the binder is usually gum arabic. Oil paints are usually thicker and contain more pigment than do watercolour paints; however, this depends on the quality of paints in question. The techniques and properties of these two forms of painting are quite different. When painting in oils, the darkest layer is applied first, then lighter layers, through to the lightest layer. When painting in watercolours, the lightest layer is applied first, then darker layers, through to the darkest layer. Oil paints require longer to dry than do watercolour paints. The oil paintings have a glossy finish compared with the matte finish of watercolour paintings. Oil paintings age well and have less discolouration over time. Watercolour paintings will fade and discolour over time if not stored well.

The advent of colour photography provided a quick means of recording plant colour. However, producing a true record of colour even with photography was challenging. The resulting colour image generated by the camera was device-dependent because of the spectral sensitivity of the sensors differing among digital cameras (Hong *et al.* 2001). Also, there was a discrepancy between recorded colour images and direct observation (Jobson *et al.* 1997). Human perception excels at constructing a visual

representation in vivid colour across a wide range of photometric levels. The recorded images of film and electronic cameras suffer from a loss of clarity and colour as light levels drop within shadows. Although the recorded images are not always true to colour, the ability of the digital camera to obtain objective colour measurements among specimens makes the digital camera a powerful tool in addressing systematic problems of colour variation (McKay 2013).

Important tools in the horticultural industry are colour charts, such as that produced by the Royal Horticultural Society (RHS; Grayer 2009) and the Munsell Book of Colour (MBC; Griesbach and Austin 2005), but it was not just gardeners who value the charts. When consulting herbarium specimens, colour is invariably lost, and language was not sufficient to definitively describe and identify colour. Colour charts can play an important role in the descriptive label that accompanies the dried pressed specimen (Grayer 2009).

Colours of plants, particularly flower colour and pattern, are important in reproductive biology especially as an isolating mechanism in pollination (Weiss 1995). A plant needs to invest energy into its colour as much as into other traits. If other traits are important in distinguishing species, then colour should not be negated as readily as Linnaeus sought to do.

Botanical illustrations or photographs? Comparative use in six contemporary journals

Blunt and Stearn (1994) suggested that in the 20th century, the photographer had largely usurped the place of the botanical artist. To ascertain whether botanical illustrations are still relevant in publications, a selection of journals, floras and monographs was examined to identify the trends in their use of both botanical illustrations and photographs.

Botanical journals

We undertook an analysis by reviewing the use of botanical illustrations and photographs in the following six peer reviewed journals: *Nuytsia* (Department of Parks and Wildlife, see https://florabase.dpaw.wa.gov.au/nuytsia/, accessed 16 June 2015), the in-house journal of the Western Australian Herbarium, first published in 1970; *Journal of the Adelaide Botanic Gardens* (Government of South Australia, Department of Environment, Water and Natural Resources, see http://www.environment.sa.gov.au/Science/Science_research/State_Herbarium/Resources/Publications/Journal_of_the_Adelaide_Botanic_Gardens, accessed 16 June 2015), the in-house journal of the South Australian Herbarium, first published in 1976 (renamed *Swainsonia* in 2017); *Muelleria* (Royal Botanic Gardens Victoria, see https://www.rbg.vic.gov.au/science/publications/muelleria/muelleria-online, accesed 24 April 2017), the in-house journal of the Royal Botanic Gardens Victoria, first published in 1955, *Telopea* (National Herbarium of New South Wales, see http://plantnet.rbgsyd.nsw.gov.au/Telopea/index.php, accessed 3 October 2017), the in-house journal of the National Herbarium of New South Wales first published in 1975; *Austrobaileya* (Queensland Government, see https://www.qld.gov.au/environment/plants-animals/plants/herbarium/austrobaileya/, accessed 4 May 2017), the in-house journal of the Queensland Herbarium, first published in 1977; and *Systematic Botany* (American Society of Plant Taxonomists, see https://aspt.net/sysbot/#.WROl4lOGORs, accessed 16 June 2015), the journal of the American Society of Plant Taxonomists, first published in 1976.

Some of these institutions employed in-house illustrators who may be employed on a full-time or part-time salary, or on a contractual basis. The services of these illustrators were often available only to the staff botanists, not to all contributors to the institutional journals, and staff botanists were not obliged to publish their papers in the in-house journal of their institution. The in-house illustrators may have their primary focus on other projects, such as floras or particular revisions, and not necessarily be directly associated with production of illustrations for journal articles. They may work particularly closely with some staff in the institution and not others as an artefact of history, personalities or funding arrangements.

The Western Australia Herbarium has not employed in-house illustrators. Instead, *Nuytsia* relied on freelance artists including Margaret Menadue, Margaret Pieroni, Lorraine Cobb and one of the authors of the present paper, Ellen Hickman. The Adelaide Botanic Gardens appointed Ludwik Dutkiewicz as botanical illustrator to its permanent staff in 1953. He was succeeded briefly by Beth Chandler in 1981, and then, in 1983, by Gilbert Dashorst, who left in 2012 (Hewson 1999). Anita Barley (nee Podwyszynski) was appointed as staff illustrator of the National Herbarium of Victoria in 1977, and remained on staff until 1992 (Twigg 1996). She was succeeded by Mali Moir (1992–1998), Su Pearson (1993–2003) and Enid Mayfield (1995–1998) in part-time positions (S. Stewart, librarian at the National Herbarium Victoria, pers. comm., 25 May 2017). This changed to contract positions in 2008 (M. Moir, pers. comm., 15 May 2017). The National Herbarium of New South Wales also employed in-house illustrators, namely Christine Payne and Robyn Griffiths, who were appointed to the staff of the herbarium in 1974 (Hewson 1999). They were succeeded by David Mackay (1979–1995, intermittently) and Nicola Oram (1989–1995), who were employed full-time concurrently, to cover the work involved in illustrating the Flora of New South Wales. Bob Roden was also employed for ~4 years during the 1980s and Marion Westmacott for ~8 years during the 1990s (D. Mackay, pers. comm., 15 May 2017). The National Herbarium of New South Wales now has one full-time illustrator position, which is job shared by Lesley Elkan (1995–present) and Catherine Wardrop (1999–present) (L. Elkan, pers. comm., 12 May 2017). Margaret Saul was the inaugural Botanical Illustrator for the Queensland Herbarium, working there from 1975 to 1980. She was succeeded by Gillian Rankin (1980–1985), and then William Smith (1985–present), who is still currently employed as a staff illustrator (W. Smith, pers. comm., 16 May 2017). So, effectively botanical staff in these institutions and, therefore, the institutional journals, namely *Journal of the Adelaide Botanic Gardens*, *Telopea*, *Muelleria* and *Austrobaileya*, have had continuous access to in-house illustrators currently or until recently.

The American Society of Plant Taxonomists was formed in 1935 ‘to foster, encourage and promote education and research in the field of plant taxonomy’ (American Society of Plant Taxonomists 2013) and is based at the University of Wyoming. The instructions to authors, for *Systematic Botany*, state that ‘papers need to include an illustration clearly showing

diagnostic characters, but a line drawing is not required.' Illustrators for *Systematic Botany* papers are employed on a commission basis by the authors of the papers, or their institutions, and are not employed by the American Society of Plant Taxonomists (see https://aspt.net/sysbot/#.WROl4lOGORs). *Systematic Botany* publishes mainly on broad taxonomic themes, and will publish new taxa within this context. *Systematic Botany* was chosen as a journal for our analysis because it publishes papers on South American taxa.

Only papers that described new species, or were revisions of particular taxa, were included in the analysis. The taxa described included vascular plants as well as fungi, lichens, mosses and algae. Papers were scored on the presence or absence of each image type, namely illustrations (including simple diagrammatic line drawings to full composite plates of plant habit and vegetative and floral traits), photographs (including SEM images, black and white and colour photography) or no visual depiction of species characteristics. The portion of papers with each image type was determined for each year of publication (Fig. 4). The year of publication was included in the analysis if at least eight papers in a particular year were describing new species or were revisions of particular taxa. At least eight papers per year were used as the cut-off to allow a balance between maintaining a sufficient number of years per journal versus a low number of papers published in any one year having a large influence on the results. We investigated temporal trends in the use of illustrations and photographs in papers with linear regression for three time periods (all years, years pre-2000 and years 2000 and after; Table 1). We chose to investigate trends before and after 2000, assuming that this marks a point in time when digital photography became more accessible to botanists. We accepted trends as statistically significant when $P < 0.05$ (Table 1, Fig. 5). All analyses were performed using StatPlus ver. 6 (AnalystSoft Inc., see http://www.analystsoft.com/en/, accessed 2 October 2016).

For *Nuytsia*, there was a significant decline in the use of illustrations for the periods 1970–2016 and 2000–2016 (Fig. 5A, Table 1). *Nuytsia* papers showed a significant decline in the use of photographs before 2000 and a significant increase in the use of photographs after 2000 (Fig. 5B, Table 1).

The *Journal of the Adelaide Botanic Gardens* showed a significant increase in the use of illustrations in papers for the period 2000–2016, but not for the other two periods (Fig. 5C, Table 1). There was also a significant increase in the use of photographs in papers for the periods 1976–2016 and 2000–2016, but not for years before 2000 (Fig. 5D, Table 1).

Muelleria displayed a significant decline in the use of illustrations in papers for the period 1983–2016 and a significant increase in the use of photographs for the same period (Fig. 5E, F, Table 1), whereas there were no significant trends in the use of either medium before or after 2000. Despite this journal being in publication since 1955, there were insufficient papers for the years of publication from 1955 to 1982, to use these years in the analysis. Hence, the resulting graph starts in the 1980s.

Telopea had a significant increase in the use of illustrations in papers for the period 1975–1999 and a significant decrease for the period 2000- 2017 (Fig. 5G, Table 1). For the period after 2000 and for the whole period 1975–2017, there was a significant increase in the use of photographs (Fig. 5H, Table 1).

Austrobaileya, in contrast, showed no trend in the use of illustrations in papers for the overall period (1977–2016) or for the periods before or after 2000. The only trend observed was a significant increase in the use of photographs in papers after 2000 (Fig. 5I, J, Table 1).

There was a significant increase in the use of illustrations in *Systematic Botany*, in papers for the overall period (1977–2016) but not for the periods before or after 2000. There was also a significant increase in the use of photographs in papers for the overall period, and before and after 2000 (Fig. 5K, L, Table 1).

To summarise, if photographs were replacing botanical illustrations as the preferred visual tool then we would expect the proportion of photographs to increase and the proportion of botanical illustrations to decrease over time, to a point where there are no botanical illustrations used in these publications. Our analysis showed that in five of the six journals, the use of photography in papers from 2000 onward has increased strongly, and for four journals this trend has been occurring since each journal was established. In contrast, in three of the six journals, the use of illustrations has declined strongly, and in two journals it has increased slightly or stayed much the same. In one journal, there was an increase in the use of illustrations after 2000, but there was no trend when all years were considered. Interestingly, there is a significant decline in the use of photographs in *Nuytsia* papers from when it was first published in 1970–2000. In some journals, botanical illustrations are being superseded by photographs, but botanical illustrations have not disappeared altogether. The cause of these trends is unknown; however, they are likely to be due to several factors, including sourcing funding for production of botanical illustrations, editorial preference for the use of illustrations or photographs, author preference for either illustrations or photographs, and moving to online publication, with no charges for colour.

Botanical monographs and floras

Botanical monographs and floras are usually published in book format, allowing the compilers more space than does the journal format, for illustrations, as either drawings or photographs.

We reviewed the use of botanical illustrations and photographs in 165 readily accessible monographs and floras on southern hemisphere regions and plant families. Only publications produced since 1950 were used. The aim was to review sufficient examples to establish quantitative trends, not to be comprehensive. Publications were scored on the presence or absence of each image type, including illustrations (including simple diagrammatic line drawings to full composite plates of plant habit and vegetative and floral traits), photographs (including SEM images, black and white and colour photography) or no visual depiction of species characteristics (Table 2). This approach has limitations, such as that a particular monograph could have many illustrations and just a single photo (or *vice versa*) and both would be equally weighted here. The trends discovered should, therefore, be regarded as indicative rather than definitive. The portion of publications

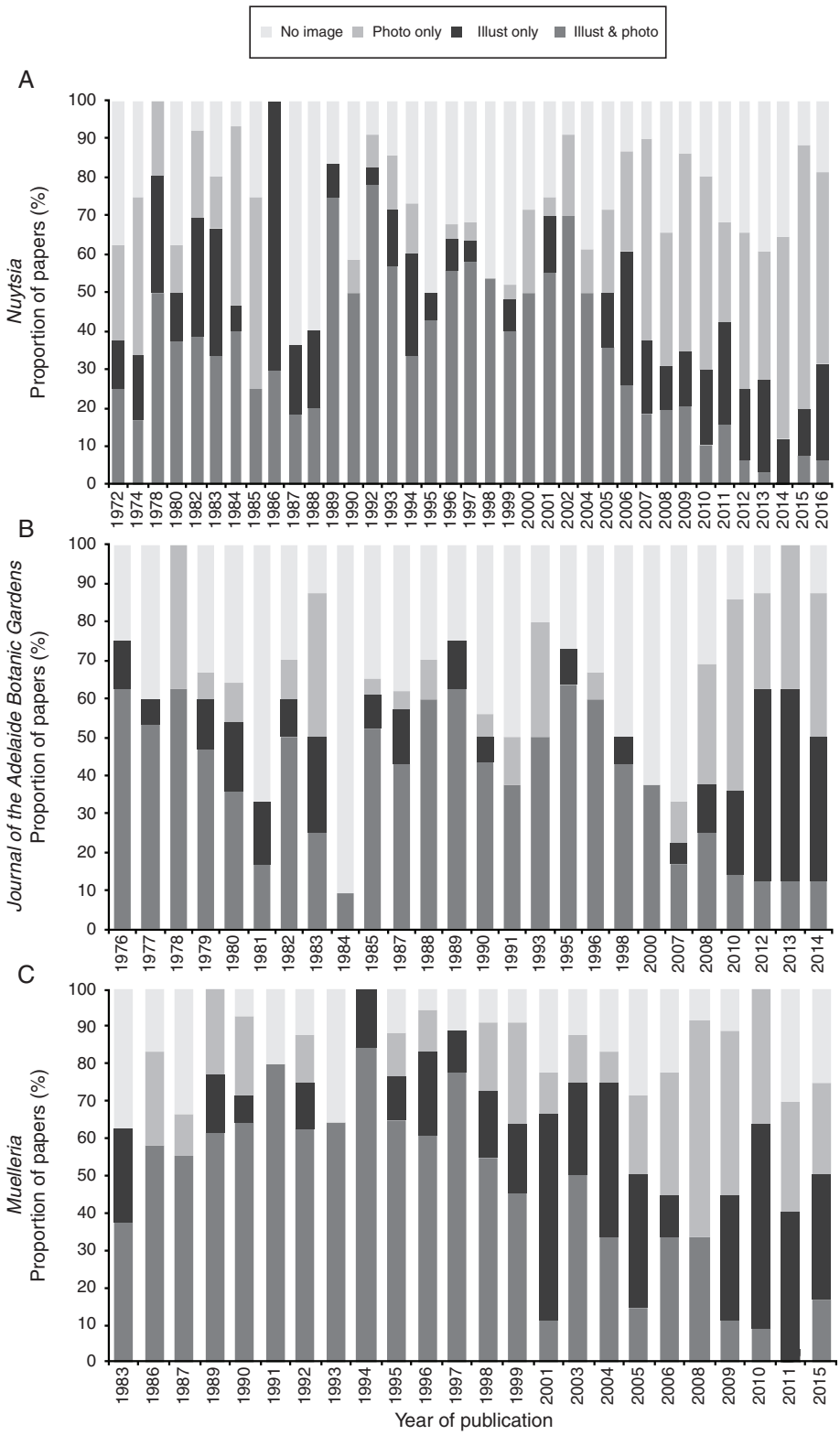

Fig. 4. The proportion of papers with illustrations, photographs or no visual depiction of species characteristics for particular years of publication of six taxonomic and plant systematic journals. A. *Nuytsia*. B. *Journal of Adelaide Botanic Gardens*. C. *Muelleria*. D. *Telopea*. E. *Austrobaileya*. F. *Systematic Botany*. Only papers that are formally describing taxa were used. Each year of publication needed to have at least eight papers before that year of publication was included in the analysis.

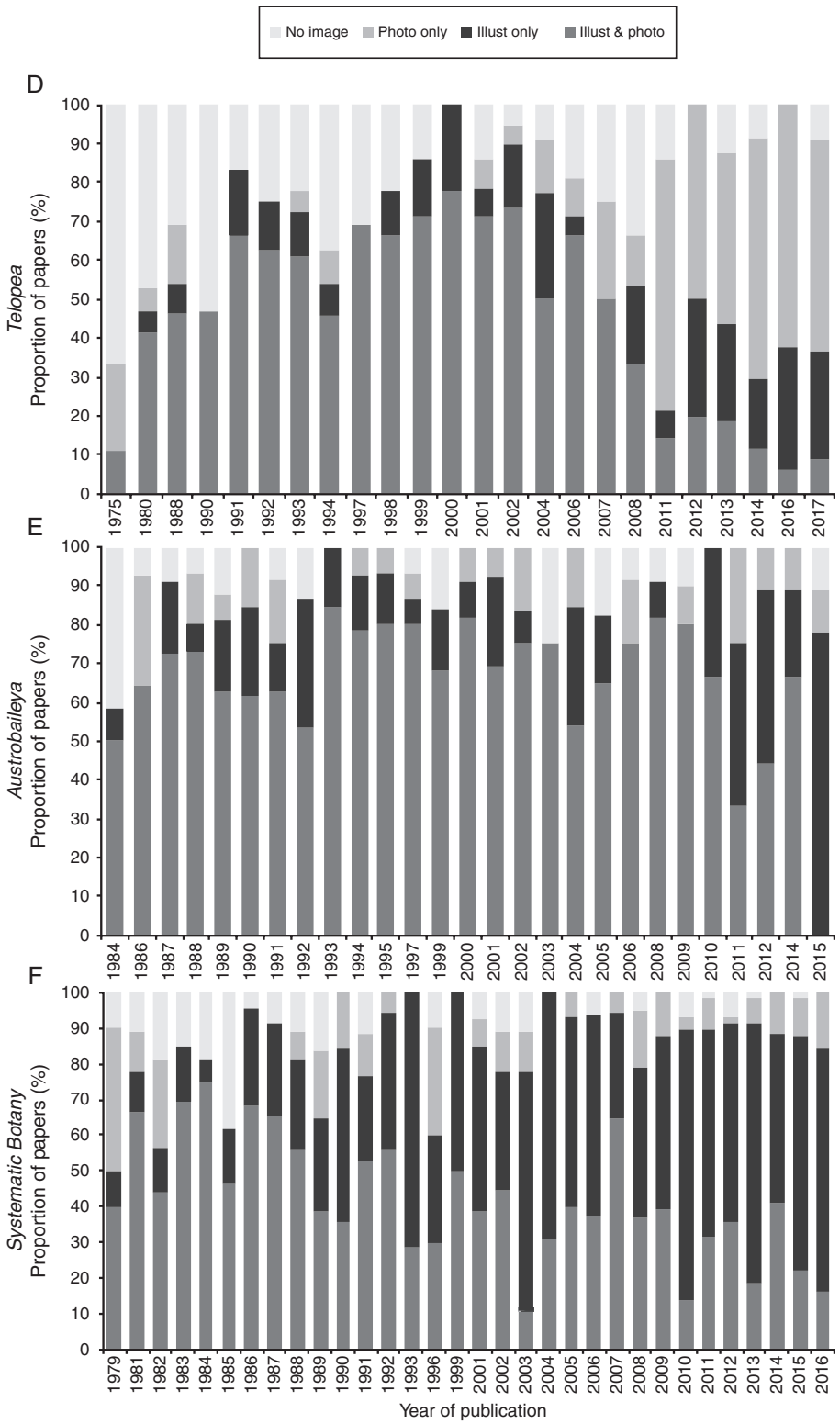

Fig. 4. (*continued*)

with each image type was determined for each decade of publication for each of three continents, namely Australia, South Africa and South America (Fig. 6A–C).

We investigated temporal trends in the use of illustrations and photographs in Australian and South African monographs and floras using linear regression. For the South African analysis,

Table 1. Linear regression analysis of the use of images in six scientific journals as a proportion of the type of image used over time
Only papers that are formally describing taxa were used. Analysis looked at all years of publication, years before 2000 and years 2000 and after. Each year of publication needed to have at least eight papers before that year of publication was included in the analysis. Significant *P*-values are italicised

Journal	Image type	Time period	Number of years used in analysis	Number of papers used in analysis	*F*	d.f.	*P*-value	r^2	Equation
Nuytsia	Illustrations	1970–2016	37	723	11.382	35	*0.002*	0.251	$Y = 11780.457 - 0.866x$
	Illustrations	1970–1999	21	307	0.143	19	0.71	0.008	$Y = -417.263 + 0.239x$
	Illustrations	2000–2016	16	416	44.83	14	*0.00001*	0.775	$Y = 6674.063 - 3.303x$
	Photographs	1970–2016	37	723	3.872	35	0.057	0.102	$Y = -1269.117 + 0.655x$
	Photographs	1970–1999	21	307	19.401	19	*0.0003*	0.519	$Y = 4361.254 - 2.179x$
	Photographs	2000–2016	16	416	24.71	14	*0.0003*	0.655	$Y = -7419.740 + 3.720x$
JABG	Illustrations	1976–2016	26	331	0.543	24	0.469	0.023	$Y = 439.091 - 0.195x$
	Illustrations	1976–1999	19	251	0.131	17	0.723	0.008	$Y = -363.962 + 0.210x$
	Illustrations	2000–2016	7	80	9.826	5	*0.035*	0.711	$Y = -9699.851 + 4.847x$
	Photographs	1976–2016	26	331	11.366	24	*0.003*	0.331	$Y = -2471.351 + 1.254x$
	Photographs	1976–1999	19	251	2.13	17	0.164	0.117	$Y = 1547.404 - 0.770x$
	Photographs	2000–2016	7	80	15.38	5	*0.017*	0.794	$Y = -16739.436 + 8.356x$
Muelleria	Illustrations	1955–2016	24	273	9.165	22	*0.006*	0.304	$Y = 2264.339 - 1.100x$
	Illustrations	1955–1999	14	167	2.27	12	0.16	0.171	$Y = -2384.516 + 1.234x$
	Illustrations	2000–2016	10	106	2.07	8	0.193	0.228	$Y = 3820.701 - 1.877x$
	Photographs	1955–2016	24	273	36.948	22	*<0.0001*	0.638	$Y = -4636.795 + 2.339x$
	Photographs	1955–1999	14	167	0.945	12	0.352	0.079	$Y = -1919.375 + 0.974x$
	Photographs	2000–2016	10	106	3.346	8	0.11	0.323	$Y = -4930.997 + 2.486x$
Telopea	Illustrations	1975–2017	24	371	4.138	22	0.055	0.165	$Y = 1758.823 - 0.848x$
	Illustrations	1975–1999	11	162	6.853	9	*0.031*	0.461	$Y = -3512.580 + 1.797x$
	Illustrations	2000–2017	13	209	25.186	11	*0.0005*	0.716	$Y = 6841.437 - 3.378x$
	Photographs	1975–2017	24	371	42.555	22	*<0.0001*	0.67	$Y = -4864.967 + 2.448x$
	Photographs	1975–1999	11	162	0.208	9	0.661	0.025	$Y = 428.970 - 0.209x$
	Photographs	2000–2017	13	209	61.281	11	*<0.0001*	0.86	$Y = -10500.304 + 5.252x$
Austrobaileya	Illustrations	1977–2016	27	369	0.121	25	0.731	0.005	$Y = -46.291 + 0.066x$
	Illustrations	1977–1999	13	211	2.852	11	0.122	0.222	$Y = -2098.958 + 1.096x$
	Illustrations	2000–2016	14	158	0.021	12	0.887	0.002	$Y = -64.735 + 0.074x$
	Photographs	1977–2016	27	369	4.258	25	0.05	0.151	$Y = -1621.977 + 0.825x$
	Photographs	1977–1999	13	211	1.424	10	0.263	0.137	$Y = 1672.314 - 0.828x$
	Photographs	2000–2016	14	158	5.755	12	*0.035*	0.343	$Y = -6463.022 + 3.236x$
Systematic Botany	Illustrations	1976–2016	32	800	6.702	30	*0.015*	0.188	$Y = -773.252 + 0.429x$
	Illustrations	1976–1999	16	266	1.132	14	0.307	0.08	$Y = -1407.011 + 0.748x$
	Illustrations	2000–2016	16	534	0.089	14	0.77	0.007	$Y = -149.106 + 0.118x$
	Photographs	1976–2016	32	800	40.085	30	*<0.0001*	0.58	$Y = -2742.950 + 1.397x$
	Photographs	1976–1999	16	266	16.11	14	*0.001*	0.553	$Y = -5083.073 + 2.575x$
	Photographs	2000–2016	6	534	7.703	14	*0.016*	0.372	$Y = -4556.566 + 2.298x$

the decade 2000s was omitted, because it contained only a single publication. The South American monograph and flora data had only a single publication cited for the 1950s and no publications cited for the decades 1960s, 1970s and 1980s, so there were insufficient data to undertake a trend analysis. This lack of publications may be due to the South American flora only recently receiving significant attention, especially compared with the Australian and South African floras, as discussed above in the historical use of botanical illustration. With the caveat of sampling bias discussed above, we accepted trends as statistically significant when $P < 0.05$ (Table 3, Fig. 6D–F). All analyses were performed using StatPlus, ver. 6 (AnalystSoft Inc.).

The use of illustrations in Australian and South African monographs did not change significantly for the decades between 1950 and 2010, but there were accompanying significant increases in the use of photography (Fig. 6D, E, Table 3).

In these monographs and floras, photographs have usually been used to show plants in their environment, or micrographs have been used to show structures such as seeds, seed coats, pollen and pollen surfaces (Fig. 3). The botanical illustrations provide details of the plant habit, structures and traits of flowers and fruits, often with the background being removed for more clarity (Figs 1, 2). Botanical illustrations also have the ability to include details from several different specimens combined, so as to show all relevant information in one image. This might not be possible in a photograph because any single specimen may not have all details visible or may have damaged structures. The results from the present review suggest that

botanical illustrations and photographs play a complementary role in monographs and floras on southern hemisphere plants, so photographs may not be usurping the place of botanical illustrations.

Roles of botanical artists in scientific discovery: who discovered what?

Our review showed that despite an increase in the use of photography, botanical illustration continues to play an

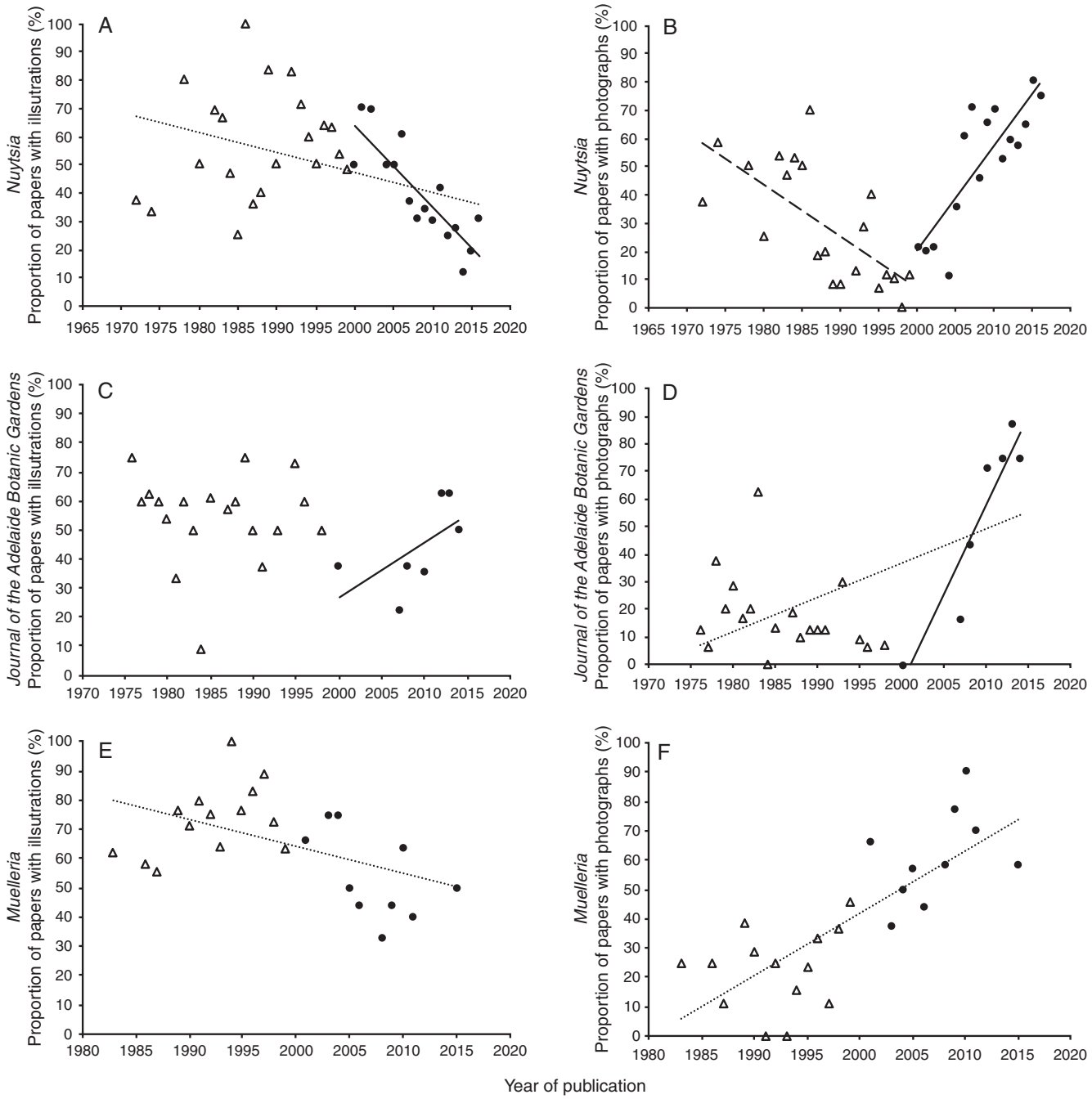

Fig. 5. Linear regression analysis of the use of images in six scientific journals as a proportion of the type of image used over time was undertaken for three time periods (all years, years pre-2000 and years 2000 and after); fitted lines are presented when the trend was significant ($P < 0.05$). A. *Nuytsia*: illustrations. B. *Nuytsia*: photographs. C. *Journal of Adelaide Botanic Gardens*: illustrations. D. *Journal of Adelaide Botanic Gardens*: photographs. E. *Muelleria*: illustrations. F. *Muelleria*: photographs. G. *Telopea*: illustrations. H. *Telopea*: photographs. I. *Austrobaileya*: illustrations. J. *Austrobaileya*: photographs. K. *Systematic Botany*: illustrations. L. *Systematic Botany*: photographs.

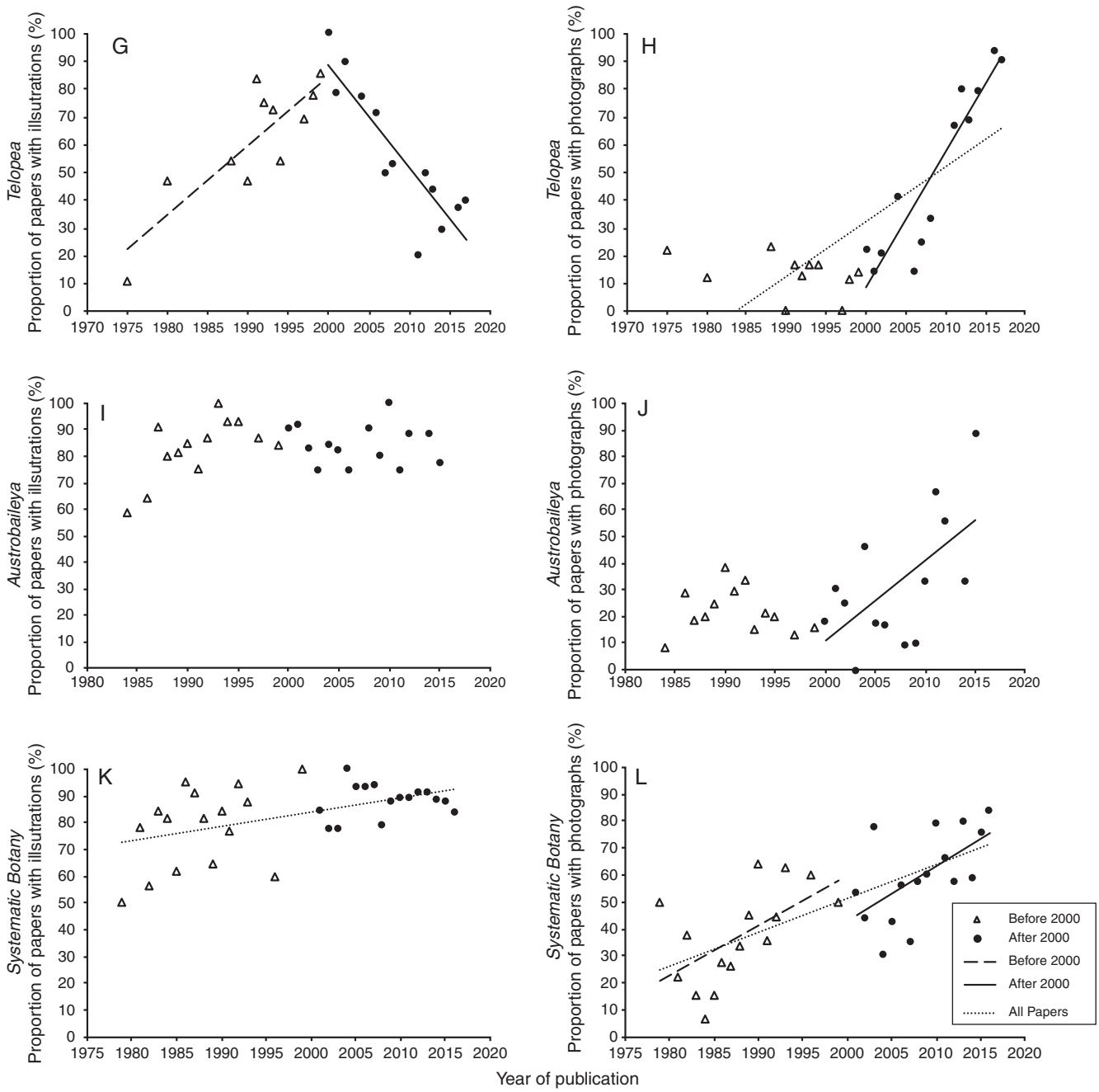

Fig. 5. (*continued*)

important role in southern hemisphere plant systematics. If the photograph has not replaced the botanical illustration as was hypothesised, then is it the skill of the practitioner that is of more importance than the type of image utilised?

There is a long history of scientists and botanical illustrators working together (Flannery 2013), but the precise role artists have played in scientific discovery is not always clear. When the botanist and artist are one and the same person, the question of who discovered what is irrelevant, but when the botanist and artist are different individuals, then the following question arises: did the scientist make a new discovery and direct the artist to illustrate it, or did the artist illustrate a new discovery that was noticed by the scientist or was pointed out by the artist to the scientist?

Discovery through illustration when a botanist was also an artist

There have been several botanists who were also botanical artists, both historically and at present day. Historically, before

Table 2. A selection of monographs and floras on southern hemisphere plants, published since 1950, by continent, in chronological order, showing the presence (1) and absence (0) of the type of images used: illustrations (illust), photographs (photo) or no image (none)

Country	Date of publication	Title	Author	Genus and FAMILY	Reference	Present (1) or absent (0)		
						Illust	Photo	None
Australia	1951	*Orchids of the West*	Erickson R	ORCHIDACEAE	Erickson 1951	1	0	0
Australia	1952	*Flora of Western Australia*	Gardner CA	POACEAE	Gardner 1952	1	0	0
Australia	1957	*Flora of South Australia*	Black J	Various	Black 1957	1	0	0
Australia	1958	*Triggerplants*	Erickson R	STYLIDIACEAE	Erickson 1958	1	0	0
Australia	1963	*The Student's Flora of Tasmania*	Curtis WM	Various	Curtis 1963	1	0	0
Australia	1968	*Eucalyptus Buds and Fruits*	Chippendale GM	*Eucalyptus*, MYRTACEAE	Chippendale 1968	1	0	0
Australia	1968	*Plants of Prey*	Erickson R	Various	Erickson 1968	1	0	0
Australia	1970	*Flora of the Australian Capital Territory*	Burbidge NT and Gray M	Various	Burbidge and Gray 1970	1	0	0
Australia	1973	*Aquatic Plants of Australia*	Ashton HI	Various	Aston 1973	1	0	0
Australia	1974	*Wildflowers of South Eastern Australia*	Garnet JR	Various	Conabere and Garnet 1975	1	0	0
Australia	1976	*The Mosses of Southern Australia*	Scott GAM, Stone IG	Mosses	Scott and Stone 1976	1	0	0
Australia	1977	*Eucalypts*	Kelly S	*Eucalyptus*, MYRTACEAE	Kelly *et al.* 1977	1	0	0
Australia	1978	*How to Know Western Australian Wildflowers*	Blackall WE and Grieve BJ	Various	Blackall and Grieve 1978	1	0	0
Australia	1978	*The Endemic Flora of Tasmania*	Curtis WM	Various	Curtis 1978	1	0	0
Australia	1979	*Lichens of South Australia*	Filson RB and Rogers RW	Lichens	Filson and Rogers 1979	1	1	0
Australia	1979	*Flora of Tasmania part 4a Angiospermae: Orchidaceae*	Curtis W	ORCHIDACEAE	Curtis 1979	1	0	0
Australia	1980	*The Mosses of South Australia*	Catcheside DG	Mosses	Catcheside 1980	1	0	0
Australia	1981	*Banksia (vols 1, 2 and 3)*	George AS	*Banksia*, PROTEACEAE	Rosser and George 1981	1	0	0
Australia	1986	*Flora of South Australia*	Jessop JP and Toelken HR (Eds)	Various	Jessop *et al.* 1986	1	0	0
Australia	1987	*Flora of the Perth Region (vols 1 and 2)*	Marchant NG Wheeler JR, Rye BL, Bennett EM, Lander NS, Macfarlane TD	Various	Marchant *et al.* 1987	1	0	0
Australia	1989	*Flora of South-Eastern Queensland (vols 1, 2 and 3)*	Stanley TD and Ross EM	Various	Stanley and Ross 1989	1	0	0
Australia	1990	*Flora of New South Wales*	Harden GJ (Ed.)	Various	Harden 1990	1	1	0
Australia	1992	*Flora of the Kimberley Region*	Wheeler JR (Ed.)	Various	Wheeler *et al.* 1992	1	0	0
Australia	1993	*Flora of Victoria*	Foreman DB, Walsh NG, Entwisle TJ (Eds)	Various	Foreman and Walsh 1993	1	0	0
Australia	1994	*The Grevillea Book (vols 1, 2 and 3)*	Olde PM and Marriot NL	*Grevillea*, PROTEACEAE	Olde and Marriott 1994	0	1	0
Australia	1995	*Flora of the Darwin Region*	Dunlop CR, Leach GJ, Cowie ID (Eds)	Various	Dunlop *et al.* 1995	1	0	0
Australia	1997	*Larger Fungi of South Australia*	Grgurinovic CA	Fungi	Grgurinovic 1997	1	1	0
Australia	1998	*Fungi of Southern Australia*	Bougher NL and Syme K	Fungi	Bougher and Syme 1998	1	0	0
Australia	1999	*Australian Rushes: Biology, Identification and Conservation of Restionaceae and Allied Families*	Meney KA and Pate JS (Eds)	RESTIONACEAE	Meney and Pate 1999	1	1	0
Australia	2002	*Flora of the South West: Bunbury Augusta Denmark*	Wheeler J, Marchant N, Lewinton M	Various	Wheeler *et al.* 2002	1	0	0
Australia	2002	*Verticordia: the Turner of Hearts*	George E	*Verticordia*, MYRTACEAE	George and Pieroni 2002	1	0	0
Australia	2002	*Flora of New South Wales*	Harden GJ (Ed.)	Various	Harden 2002	1	1	0
Australia	2003	*Marine Benthic Flora of Southern Australia*	Womersley HBS	Algae	Womersley 2003	1	1	0
Australia	2006	*Plants of the Adelaide Plains and Hills (3rd edn)*	Dashorst GRM and Jessop JP	Various	Dashorst and Jessop 2006	1	0	0
Australia	2006	*Grasses of South Australia*	Jessop JP, Dashorst GRM and James FM	Grasses	Jessop *et al.* 2006	1	1	0
Australia	2006	*Flora of Australia vol. 51 Mosses 1*	McCarthy PM	Mosses	McCarthy 2006	1	1	0
Australia	2007	*Eremophila and Allied Genera*	Chinnock RJ	*Eremophila* MYOPORACEAE	Chinnock 2007	1	1	0
Australia	2008	*Orchids of Western Australia*	Brown A, Dundas P, Dixon K and Hopper S	ORCHIDACEAE	Brown *et al.* 2008	1	0	0
Australia	2009	*Flora of Australia vol. 44 A Poaceae 2*	Wilson A (Ed.)	POACEAE	Wilson 2009	1	1	0
Australia	2009	*Flora of Australia vol. 57 Lichens 5*	McCarthy PM and Kuchlmayr B (Ed.)	Lichens	McCarthy and Kuchlmayr 2009	1	1	0
Australia	2011	*Flora of Australia vol. 39 Alismatales to Arales*	Wilson A (Ed.)	Alismatales to Arales	Wilson 2011	1	1	0

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Table 2. (*continued*)

Country	Date of publication	Title	Author	Genus and FAMILY	Reference	Present (1) or absent (0) Illust	Photo	None
Australia	2013	*Flora of Australia vol. 26 Meliaceae, Rutaceae and Zygophyllaceae*	Wilson A (Ed.)	MELIACEAE, RUTACEAE, ZYGOPHYLLACEAE	Wilson 2013	1	1	0
Australia	2015	*Flora of Australia vol. 37 Asteraceae 1*	Wilson A (Ed.)	ASTERACEAE	Wilson 2015	1	1	0
Australia	2016	*Flora of South Australia (5th edn)*	Kellerman J (Ed.)	Various	Kellerman 2016	1	1	0
South Africa	1950	*Wildflowers of the Cape of Good Hope*	Compton RH and Garrett Rice E	Various	Rice and Compton 1950	1	0	0
South Africa	1952	*Stapelieae of Southern Africa*	Lückhoff CA	ASCLEPIADACEAE	Lückhoff 1952	0	1	0
South Africa	1954	*Wild Flowers of Natal*	Hulme MM	Various	Hulme 1954	1	0	0
South Africa	1955	*Common Succulents*	Hall H	Various	Hall 1955	1	0	0
South Africa	1959	*The Genus* Babiana	Lewis GJ	*Babiana*, IRIDACEAE	Lewis 1959	1	1	0
South Africa	1962	*Wild Flowers of the Transvaal*	Letty C and Dyer RA	Various	Letty and Dyer 1962	1	0	0
South Africa	1966	*Wildflowers of the Eastern Cape*	Batten AU, Bokelmann HL	Various	Batten and Bokelmann 1966	1	0	0
South Africa	1967	*Ericas of Southern Africa*	Baker HA and Oliver EGH	ERICACEAE	Baker and Oliver 1967	1	0	0
South Africa	1967	*The Flowering Plants of the Tsitskama Forest & Coastal Park*	Couryenay-Latimer M and Smith GG	Various	Courtenay-Latimer and Smith 1967	1	0	0
South Africa	1969	*South African Aloes*	Jeppe BJ	Various	Jeppe 1969	1	0	0
South Africa	1971	*The Genera of Mesembryanthemaceae*	Herre H	MESEMBRYANTHEMACEAE	Herre 1971	1	0	0
South Africa	1971	*Wild Flowers of the Witwatersrand*	Lucas A	Various	Lucas 1971	1	0	0
South Africa	1972	*The Genus Romulea in South Africa*	De Vos MP	*Romulea*, IRIDACEAE	De Vos 1972	1	1	0
South Africa	1972	*A Revision of the South African Species of Gladiolus*	Lewis GJ, Obermeyer AA and Barnard TT	*Gladiolus*, IRIDACEAE	Lewis *et al.* 1972	1	0	0
South Africa	1972	*South African Erythrinas*	Hennessy EF	*Erythrinas*	Hennessy 1972	1	0	0
South Africa	1973	*Ferns of the Witwatersrand*	Hancock FD and Lucas A	Various	Hancock and Lucas 1973	1	0	0
South Africa	1974	*Aloes*	Jeppe BJ	Various	Jeppe 1974	1	1	0
South Africa	1974	*Cycads of South Africa*	Giddy C	Various	Giddy 1974	1	1	0
South Africa	1975	*Natal Wild Flowers*	Jeppe BJ	Various	Jeppe 1975	1	0	0
South Africa	1975	*Wild Flowers of Malawi*	Moriarty A	Various	Moriarty 1975	1	0	0
South Africa	1975	*Wild Flowers of Natal: Coastal Region*	Gibson JM	Various	Gibson 1975	1	0	0
South Africa	1976	*The South African Acacias*	Carr D	*Acacia*, FABACEAE	Carr 1976	1	1	0
South Africa	1977	*A Field Guide to the Trees of Southern Africa*	Palmer E	Various	Palmer 1977	1	0	0
South Africa	1977	*Compositae in Natal*	Hilliard OM	ASTERACEAE	Hilliard 1977	1	0	0
South Africa	1978	*Wild Flowers of Natal: Inland Region*	Gibson JM	Various	Gibson 1978	1	0	0
South Africa	1978	*Southern African Epiphytic Orchids*	Ball JS, Browning J and Ashton P	ORCHIDACEAE	Ball *et al.* 1978	1	0	0
South Africa	1979	*Cape Peninsula Ferns*	Roux JP	Various	Roux 1979	1	0	0
South Africa	1980	*The Proteas of South Africa*	Rourke JP	*Protea*, PROTEACEAE	Rourke 1980	1	1	0
South Africa	1981	*Orchids of Africa*	Hennessy EF and Stewart J	ORCHIDACEAE	Hennessy 1981	1	0	0
South Africa	1981	*Flora of Southern Africa, Bryophyta part 1*	Magill R	Bryophyta	Magill 1981	1	0	0
South Africa	1982	*Mimetes*	Rourke JP and Lincoln T	*Mimetes*, PROTEACEAE	Rourke and Lincoln 1982	1	0	0
South Africa	1982	*Transvaal Wild Flowers*	Fabian A and Germishuizen G	Various	Fabian and Germishuizen 1982	1	0	0
South Africa	1982	*The Fern Genus Elaphoglossum Schott (Filicales) in South Africa in Journal of South African Botany 48*	Roux JP	*Elaphoglossum*	Roux 1982	1	1	0
South Africa	1984	*Revision of the Genus Haemanthus*	Snijman DA	*Haemanthus*, AMARYLLIDACEAE	Snijman 1984	1	0	0
South Africa	1984	*Studies on African Asclepiadaceae*	Kupicha FK	ASCLEPIADACEAE	Kupicha 1984	1	1	0

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Table 2. (*continued*)

Country	Date of publication	Title	Author	Genus and FAMILY	Reference	Present (1) or absent (0) Illust	Photo	None
South Africa	1985	*Trees & Shrubs of the Natal Drakensburg*	Hilliard OM	Various	Hilliard 1985	1	0	0
South Africa	1986	*The Moraeas of South Africa: a Systematic Monograph of the Genus in South Africa, Lesotho, Swaziland, Transkei, Botswana, Namibia and Zimbabwe*	Goldblatt P	*Moraea* IRIDACEAE	Goldblatt 1986	1	0	0
South Africa	1986	*Pteridophyta*	Schelpe EA and Anthony NC	Various	Schelpe and Anthony 1986	1	1	0
South Africa	1986	*Flowering Plants of the Southern Cape*	Pauline Bohnen	Various	Bohnen 1986	1	0	0
South Africa	1986	*Namib Flora*	Craven P	Various	Craven and Marais 1986	1	0	0
South Africa	1987	*Grasses, Sedges, Restiads & Rushes of the Natal Drakensburg*	Hilliard OM	Various	Hilliard 1987	1	1	0
South Africa	1987	*Flora of Southern Africa, Bryophyta part 2*	Magill R	Bryophyta	Magill 1987	1	0	0
South Africa	1988	*Pelargoniums of Southern Africa vol 3*	Van der Walt JJA and Vorster PJ	*Pelargonium* GERANIACEAE	Van der Walt and Vorster 1988	1	0	0
South Africa	1988	*Combretaceae in Southern Africa*	Carr D	COMBRETACEAE	Carr 1988	1	1	0
South Africa	1989	*Bulbous Plants of South Africa*	du Plessis N and Duncan G	Various	Du Plessis and Duncan 1989	1	0	0
South Africa	1989	*Cycads of Africa*	Douglas Goode		Goode 1989	1	0	0
South Africa	1989	*The Slipper Orchids*	Hennessy EF and Hedge TA	ORCHIDACEAE	Hennessy and Hedge 1989	1	0	0
South Africa	1989	*Waterberg Flora*	Craven P	Various	Craven and Marais 1989	1	0	0
South Africa	1990	*Grasses of South Africa*	Gibbs Russell GE, Watson L, Koeekemoer M, Smook L, Barker NP, Anderson HM, and Dallwitz MJ	POACEAE	Gibbs Russell *et al.* 1990	1	1	0
South Africa	1990	*Southern African Ferns & Fern Allies*	Burrows JE	Ferns	Burrows 1990	1	1	0
South Africa	1991	*Dierama*	Hilliard OM and Burtt BL	*Dierama* IRIDACEAE	Hilliard and Burtt 1991	1	0	0
South Africa	1992	*Succulents of the Transvaal*	Hardy D	Various	Hardy 1992	1	0	0
South Africa	1992	*The Marine Red Algae of Natal*	Norris RE		Norris 1992	1	0	0
South Africa	1992	*Damaraland Flora*	Craven P	Various	Craven and Marais 1992	1	0	0
South Africa	1993	*The Complete Field Guide to Trees of Natal, Zululand & Transkei*	Pooley E	Various	Pooley 1993	1	1	0
South Africa	1993	*The Woody Iridaceae: Systematics, Biology and Evolution of Nivenia, Klattia and Witsenia.*	Goldblatt P	IRIDACEAE	Goldblatt 1993	1	0	0
South Africa	1994	*Gasterias of South Africa*	Van Jaarsveld EJ Ward-Hilhorst E	*Gasteria* ASPHODELACEAE	Van Jaarsveld and Ward-Hilhorst 1994	1	0	0
South Africa	1995	*The Proteas of Tropical Africa*	Beard JS	*Protea* PROTEACEAE	Beard 1995	1	1	0
South Africa	1995	*Cyperaceae in Natal*	Gordon-Gray KD	CYPERACEAE	Gordon-Gray 1995	1	1	0
South Africa	1996	*Wild Flowers of Kwazulu – Natal*	Walker J	Various	Walker 1996	1	0	0
South Africa	1997	*Wildflowers of Northern South Africa*	Fabian A and Germishuizen G	Various	Fabian and Germishuizen 1997	1	0	0
South Africa	1997	*Plants of the Okavango Delta: a Field Guide*	Ellery K and Ellery W	Various	Ellery and Ellery 1997	1	0	0
South Africa	1998	*Gladiolus in Southern Africa*	Goldblatt P and Manning J	*Gladiolus* IRIDACEAE	Goldblatt and Manning 1998	1	0	0
South Africa	1998	*A Field Guide to the Wildflowers: Kwazulu-Natal & the Eastern Region*	Pooley B	Various	Pooley 1998	1	1	0
South Africa	1998	*Flora Hercsheliana*	Warner B and Rourke J	Various	Warner and Rourke 1999	1	0	0
South Africa	1999	*Orchids of Southern Africa*	Linder HP and Kurweil H	ORCHIDACEAE	Linder and Kurzweil 1999	1	1	0
South Africa	1999	*Irises*	Jeppe BJ	IRIDACEAE	Jeppe 1999	1	0	0

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Table 2. (*continued*)

Country	Date of publication	Title	Author	Genus and FAMILY	Reference	Present (1) or absent (0) Illust	Photo	None
South Africa	1999	*Bulbinella in South Africa in Strelitzia 8*	Perry PL	*Bulbinella* ASPHODELACEAE	Perry 1999	1	1	0
South Africa	2001	*Geophytic Pelargoniums*	Craib C	*Pelargonium* GERANIACEAE	Craib 2001	1	0	0
South Africa	2012	*Restios of the Fynbos*	Dorrat-Haaksma E and Linder HP	RESTIONACEAE	Dorrat-Haaksma and Linder 2012	0	1	0
South Africa	2013	*Plants of the Greater Cape Floristic Region 2: the Extra Cape Flora in Strelitzia 30*	Snijman DA	Various	Snijman 2013	0	0	1
South Africa	2015	*Wildflowers of Namaqualand*	Roux A	Various	Roux 2015	0	1	0
South America	1959	*Venezuelan Orchids Illustrated vol. I*	Dunsterville, GCK and Garay LA	ORCHIDACEAE	Dunsterville and Garay 1959	1	1	0
South America	1993	*Haeomodraceae (Flora Neotropica Monograph 61)*	Maas PJM and Maas-van de Kramer H	HAEMODORACEAE	Maas and Maas-van de Kramer 1993	1	1	0
South America	1994	*Flora De San Juan, Republica Argentina: vol. 1*	Kiesling R	Various	Kiesling 1994	1	1	0
South America	1995	*Flora of Venezuela Guyana vol. 2 PTERIDOPHYTES, SPERMATOPHYTES, ACANTHACEAE – ARACEAE*	Steyermark JA, Berry PE, Holst BK	PTERIDOPHYTES, SPERMATOPHYTES, ACANTHACEAE–ARACEAE	Steyermark *et al.* 1995	1	0	0
South America	1997	*Flora of Venezuela Guyana vol. 3 ARALIACEAE– CACTACEAE*	Steyermark JA, Berry PE, Holst BK	ARALIACEAE – CACTACEAE	Steyermark *et al.* 1997	1	0	0
South America	1998	*Flora of Venezuela Guyana vol. 4 CAESALPINACEAE – ERICACEAE*	Steyermark JA, Berry PE, Holst BK	CAESALPINACEAE – ERICACEAE	Steyermark *et al.* 1998	1	0	0
South America	1998	*Familias De Plantas Neotropicales*	Maas PJM, Westra LYTh	Various	Maas & Westra 1998	1	0	0
South America	1999	*Flora of Venezuela Guyana vol. 5 ERIOCAULACEAE – LENTIBULARIACEAE*	Steyermark JA, Berry PE, Yatskievych K, Holst BK	ERIOCAULACEAE – LENTIBULARIACEAE	Steyermark *et al.* 1999	1	0	0
South America	2000	*Cladoniaceae (Flora Neotropica Monograph 78)*	Ahti T	CLADONIACEAE	Ahti 2000	1	1	0
South America	2000	*Buddlejaceae (Flora Neotropica Monograph 81)*	Norman E	BUDDLEJACEAE	Norman 2000	1	1	0
South America	2000	*Vitaceae: Generos Ampelocissus, Ampelopsis E Cissus (Flora Neotropica Monograph 80)*	Lombardi JA	VITACEAE	Lombardi 2000	1	1	0
South America	2000	*Opiliaceae (Flora Neoptropica Monograph 82)*	Hiepko P	OPILIACEAE	Hiepko 2000	1	1	0
South America	2001	*Flora of Venezuela Guyana vol. 6 LILIACEAE – MYRSINACEAE*	Steyermark JA, Berry PE, Yatskievych K, Holst BK	LILIACEAE-MYRSINACEAE	Steyermark *et al.* 2001	1	0	0
South America	2002	*Brazilian Trees: a Guide to the Cultivation and Identification of Brazilian Trees*	Lorenzi H	Various	Lorenzi 2002	0	1	0
South America	2002	*Solanum Section Geminata (Solanaceae) (Flora Neotropica Monogaph 84)*	Knapp S	SOLANACEAE	Knapp 2002	1	1	0
South America	2003	*Flora De San Juan, Republica Argentina: vol. 2*	Roberto Kiesling	Various	Kiesling 2003	1	1	0
South America	2003	*Potamogetonaceae (Flora Neotropica Monograph 85)*	Haynes RR, Holm-nielsen LB	POTAMOGETONACEAE	Haynes and Holm-Nielsen 2003	1	0	0
South America	2003	*Melicocceae (Sapindaceae) Melicoccus and Talisia (Flora Neotropica Monograph 87)*	Acevedo-Rodriguez P	SAPINDACEAE	Acevedo-Rodriguez 2003	1	1	0
South America	2003	*Duguetia (Annonaceae) (Flora Neotropica Monograph 88)*	Maas PJM, Westra LYTh, Chatrou LW	ANNONACEAE	Maas *et al.* 2003	1	1	0
South America	2003	*Ceratolejeunea (Flora Neotropica Monograph 90)*	Dauphin G		Dauphin 2003	1	1	0
South America	2004	*Florula del Parque Nacional Natural Amacayacu Amazonas, Colombia (Msb 99)*	Rudas Lleras, Agustín; Prieto Cruz, Adriana	Various	Rudas Lleras and Prieto Cruz 2004	1	0	0
South America	2004	*Lauraceae: Endlicheria (Flora Neotropica Monograph 91)*	Chanderbali AS	LAURACEAE	Chanderbali 2004	1	1	0
South America	2004	*Lauraceae: Rhodostemonodaphne (Flora Neotropica Monograph 92)*	Madrinan S	LAURACEAE	Madrinan 2004	1	1	0

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Table 2. (*continued*)

Country	Date of publication	Title	Author	Genus and FAMILY	Reference	Present (1) or absent (0) Illust	Photo	None
South America	2005	*Flora of Venezuela Guyana vol. 9 Rutaceae – Zygophyllaceae*	Steyermark JA, Berry PE, Yatskievych K, Holst BK	RUTACEAE – ZYGOPHYLLACEAE	Steyermark *et al.* 2005	1	0	0
South America	2005	*Cecropia (Flora Neotropica Monograph 94)*	Berg CC, Rosselli PF	CECROPIACEAE	Berg and Rosselli 2005	1	0	0
South America	2005	*Siparunaceae (Flora Neotropica Monograph 95)*	Renner SS, Hausner G	SIPARUNACEAE	Renner and Hausner 2005	1	1	0
South America	2005	*Drosera (Droseraceae) (Flora Neotropica Monograph 96)*	Correa MD, Silva TRS	DROSERACEAE	Correa and Silva 2005	1	1	0
South America	2005	*Tococa (Melastomataceae) (Flora Neotropica Monograph 98)*	Michelangeli FA	MELASTOMATACEAE	Michelangeli 2005	1	1	0
South America	2007	*Piptocarpha (Compositae: Vernonieae) (Flora Neotropica Monograph 99)*	Smith GL, Coile NC	ASTERACEAE	Smith and Coile 2007	1	1	0
South America	2007	*Proteaceae (Flora Neotropica Monograph 100)*	Prance GT, Plana V, Edwards KS, Pennington RT	PROTEACEAE	Prance *et al.* 2007	1	1	0
South America	2007	*Fissidentaceae (Flora Neotropica Monograph 101)*	Pursell RA	FISSIDENTACEAE	Pursell 2007	1	0	0
South America	2008	*Metzgeriaceae (Hepaticae) (Flora Neotropica Monograph 102)*	Pinheiro da Costa D	METZGERIACEAE	Pinheiro da Costa 2008	1	0	0
South America	2009	*Flora de San Juan, Republica Argentina: vol. Iv*	Kiesling R	Various	Kiesling 2009	1	1	0
South America	2010	*Brazilian Flora: 'Arecaceae' (Palms)*	Lorenzi H	ARECACEAE	Lorenzi 2010	0	1	0
South America	2010	*Flora Del Rio Cenepa, Amazonas, Peru (Msb 114)*	Martínez RV, Gonzáles RR, Van der Werff H	Various	Martínez *et al.* 2010	0	1	0
South America	2010	*Theophrastaceae (Flora Neotropica Monograp 105)*	Stahl B	THEOPHRASTACEAE	Stahl 2010	1	1	0
South America	2010	*Combretaceae (Flora Neotropica Monograph 107)*	Stace C	COMBRETACEAE	Stace 2010	1	1	0
South America	2010	*Disterigma (Ericaceae: Vaccinieae) (Flora Neotropica Monograph 108)*	Pedraza-Peñalosa P	ERICACEAE	Pedraza-Penalosa 2010	1	1	0
South America	2011	*Gunneraceae (Flora Neotropica Monograph 109)*	Mora-Osejo LE, Pabon-Mora N, Gonzalez F	GUNNERACEAE	Mora-Osejo *et al.* 2011	1	1	0
South America	2012	*Jatropha (Euphorbiaceae) (Flora Neotropica Monograph 110)*	Dehgan B	EUPHORBIACEAE	Dehgan 2012	1	0	0
South America	2014	*Catálogo de Las Plantas Vasculares de Bolivia (Msb 127)*	Jørgensen PM, Nee MH, Beck SG	Various	Jørgensen *et al.* 2014	0	0	1
South America	2014	*Flora de La República de Cuba, series A: Plantas Vasculares, Fascículo 19: Buxaceae, Lauraceae, Theophrastaceae*	Köhler E, Rohwer JG, Lepper L, Gutierrez Amaro JE	BUXACEAE, LAURACEAE, THEOPHRASTACEAE	Köhler *et al.* 2014	0	1	0
South America	2014	*Flora of Guaramacal Venezuela): Monocotyledons*	Dorr LJ	Various	Dorr 2014	1	1	0
South America	2014	*Celastraceae (Hippocrateoideae E Sallacioideae) (Flora Neotropica Monograph 114)*	Lombardi JA	CELASRACEAE	Lombardi 2014	1	1	0
South America	2015	*Flora de La República de Cuba, series A: Plantas Vasculares, Fascículo 21 (2-volume set): Poaceae II: Pharoideae A Chloridoideae.*	Catasús Guerra L (author), Greuter W and Rodriguez RR (Eds)	POACEAE	Catasús Guerra *et al.* 2015	0	1	0
South America	2016	*Quiinaceae (Flora Neotropica Monograph 115)*	Schneider JV, Zizka G	QUIINACEAE	Schneider and Zizka 2016	1	0	0
South America	2016	*Prionolejeunea: Lejeuneaceae, Jungermanniopsida (Flora Neotropica Monograph 116)*	Ilkiu-Borges AL	LEJEUNEACEAE	Ilkiu-Borges 2016	1	0	0
South America	2016	*Anemia (Anemiaceae) (Flora Neotropica Monograph 118)*	Mickel JT	ANEMIACEAE	Mickel 2016	1	0	0
South America	2017	*Orchids of the Guianas (Guyana, Suriname, French Guiana), vol. 1*	Szalechetko DL, Nowak S, Baranov P, Kolanowska M	ORCHIDACEAE	Szalechetko *et al.* 2017	1	1	0

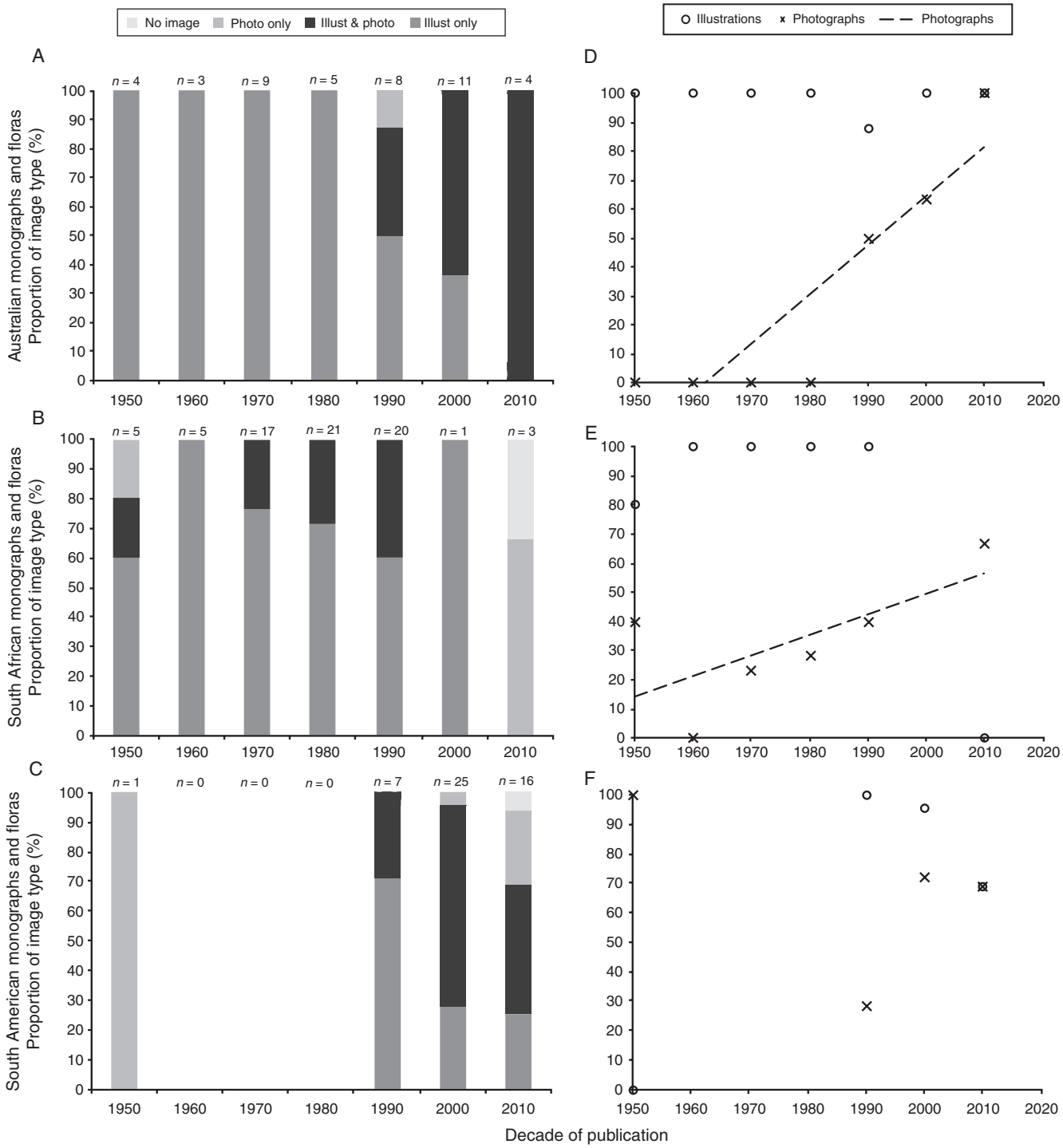

Fig. 6. The proportion of image type used in a selection of monographs and floras on southern hemisphere plants. A–C. The proportion of papers with illustrations (Illust), photographs (Photo) or no visual depiction of species characteristics in publication for a particular decade since 1950 (n = number of publications scored for each decade). A. Australia. B. South Africa. C. South America. D–F. Linear regression analysis of the use of image type over time; fitted lines are presented when the trend was significant ($P < 0.05$). D. Australia. E. South Africa. F. South America.

the advent of the camera, being able to make sketches of findings was very important, particularly if the collections did not survive the rigours of climate and transportation, as was the case with Nikolaus Joseph Jacquin's (1727–1817) Caribbean collections. In the absence of his specimens, his sketches became the basis of one of Jacquin's most celebrated works, *Selectarum Stirpium Americanarum Historia* (*c.* 1780; Sherwood *et al.* 2005). In some cases, the workload of being both scientist and

Table 3. Linear regression analysis of the use of images in monographs and floras on southern hemisphere regions and plant families by decade as a proportion of the type of image used over time
Significant *P*-values are italicised

Country	Image type	Time period	Number of decades used in analysis	Number of publications used in analysis	*F*	d.f.	*P*-value	r^2	Equation
Australia	Illustrations	1950–2017	7	44	0.07	5	0.805	0.017	$Y = 168.810 - 0.036x$
Australia	Photographs	1950–2017	7	44	28.482	5	*0.006*	0.877	$Y = -4165.794 + 2.117x$
South Africa	Illustrations	1950–2017	6	72	5.880	4	0.094	0.662	$Y = 3829.730 - 1.892x$
South Africa	Photographs	1950–2017	6	72	103.196	4	*0.002*	0.972	$Y = -2443.597 + 1.249x$
South America	Illustrations	1950–2017	–	–	–	–	–	–	–
South America	Photographs	1950–2017	–	–	–	–	–	–	–

artist was too much and the individual had to make a choice between concentrating on the art or the science. William Jackson Hooker encountered this dilemma when illustrating for *Curtis's Botanical Magazine*. In 1834, Walter Hood Fitch (1817–1892) began to relieve Hooker of the burden of illustration (Blunt and Stearn 1994). In most cases, these botanists and artists have demonstrated their discoveries of new taxa and characters through the publication of their findings, accompanied by their illustrations. Examples include William Henry Harvey's (1811–1866) five-volume work, *Phycologia Australica* (Harvey 1858, 1859, 1860, 1862, 1863), Frederica (Rica) Lucy Erickson's *Orchids of the West* (Erickson 1951), *Triggerplants* (Erickson 1958) and *Plants of Prey* (Erickson 1958), and Allen Lowrie's (1948–present) *Carnivorous Plants of Australia* in three volumes (Lowrie 1987, 1989, 1998, Lowrie and Robinson 2013), with a fourth being currently in the making.

Probably two of the best-known botanical illustrators who were not honoured with the title botanist, were the Bauer brothers. Both collected and illustrated their botanical discoveries in *Illustrations of Orchidaceous Plants* (Bauer and Lindley 1838) by Francis Bauer and *Illustrationes Florae Novae Hollandiae* (Bauer 1813) by Ferdinand Bauer. Table 4 lists these along with a selection of other botanists who were also botanical illustrators, with their areas of study and the publications in which they demonstrated their scientific and illustrated discoveries.

Discovery through illustration when botanist and artist were separate individuals

We could assume that when a taxonomist names a plant in the honour of an artist that this is recognition of the latter's contribution. Artists, through their interest in the subject and eye for detail, were able to recognise new species and illustrate their distinguishing traits. Ferdinand von Mueller (1825–1896), first Government Botanist of Victoria, Australia, often named plants in honour of 'his illustrating and collecting ladies' (Olsen 2013); that is the women who both collected specimens and provided the illustrations to support his scientific work. He named a Tasmanian cushion daisy, *Antennaria meredithae* (now *Ewartia meredithae* (F.Muell.) Beauverd), for Louisa Anne Meredith (1812–1895), and wrote:

> I avail myself of this opportunity of attaching to this everlasting the name of a lady, who by her artistic skill, her fondness for flowers, and her literary accomplishments, has much contributed to raise a taste for the local study of the lovely Tasmanian vegetation [Olsen 2013, p. 5].

Joseph Henry Maiden, Government Botanist and Director of the Royal Botanic Garden, Sydney, considered Margaret Flockton 'the most accomplished botanical artist in New South Wales' (Wilson 2016, p. 171). In recognition of her contributions to botanical art, and referring to her as the joint author of his works, Maiden named several species for her, including *Eucalyptus flocktoniae* Maiden, *Acacia flocktoniae* Maiden and *Olearia flocktoniae* Maiden & Betche (Wilson 2016).

The monospecific orchid genus *Ericksonella* Hopper & A.P.Br. was named for Dr Rica Erickson, author, historian, wildflower artist and botanist, who wrote *Orchids of the West* (Erickson 1951), and continued to paint orchids and write about them into her 90s (Hopper and Brown 2004). *Cyanicula nikulinskyae* Hopper & A.P.Br. was 'named for Philippa Nikulinsky, an internationally renowned wildflower artist, whose fine contribution in celebrating the Western Australian flora have heightened appreciation and conservation of this rich natural heritage' (Hopper and Brown 2000, p. 124). *Caladenia dundasiae* Hopper & A.P.Br. was named 'after Patricia Dundas, botanical artist and keen orchid enthusiast, who first drew the species to our attention.' (Hopper and Brown 2001, p. 219).

There are publications where the botanical illustrator is listed as an author. From this, we can infer a clear acknowledgement of the botanical illustrator's contribution to the content of the publication. However, it is unclear whether or not the acknowledgement encompasses scientific discoveries through their artwork. Examples of this include *Fungi of Southern Australia* (Bougher and Syme, 1998), *Verticordia: the Turner of Hearts* (George and Pieroni 2002), *Orchids of Western Australia* (Brown *et al.* 2008) and Haemodoraceae in the *Flora of Australia, Vol. 45: Hydatellaceae to Liliaceae* (Macfarlane *et al.* 1987). Recent changes by some scientific journals, to clarify the role and contributions of co-authors, may in the future allow better understanding of who made these discoveries.

There are also publications where the botanical illustrator is the lead author or sole author. This is even more demonstrative of the artist's contribution, but, again, it is unclear whether this encompasses scientific discoveries, or is just the documentation

Table 4. A selected list of botanists and botanical artists with their areas of study and significant publications in which they demonstrated their scientific and illustrated discoveries, in a chronological order

Person	Date	Skills	Area of study and significant publications	Reference
Hendrik Bernhard Oldenland	1663–1697	Botanist, botanical illustrator	*Index Alter Plantarum* (1720)	Arnold 2001
Mark Catesby	1682–1749	Botanist, botanical illustrator	American flora; *The Natural History of Carolina, Florida, and the Bahama Islands* (1731–1747)	Rix 2012
Nikolaus Joseph Jacquin	1727–1817	Botanist, chemist, physician, botanical illustrator	Caribbean flora, Greek flora; *Selectarum Stirpium Americanarum Historia* (*c.*1780)	Sherwood *et al*. 2005
Franz Andreas Bauer	1758–1840	Botanical illustrator, microscopist	Artist for Royal Botanic Garden Kew; *Illustrations of Orchidaceous Plants by Francis Bauer* (1830–1838)	Watts *et al*. 1997; CHAH 2014*a*
Ferdinand Lukas Bauer	1760–1826	Botanical illustrator	*Flora Graeca* (1806–1840); *Illustrationes Florae Novae Hollandiae* (1806–1813)	George 2009; CHAH 2014*b*
William Jackson Hooker	1785–1865	Botanist, botanical illustrator,	Director Royal Botanic Gardens Kew; *Curtis's Botanical Magazine* (38 volumes, 1827–1865)	Blunt and Stearn 1994; Orchard 1999; CHAH 2016
Joseph Dalton Hooker	1785–1865	Botanist, botanical illustrator	Director Royal Botanic Gardens, Kew; *Flora Antarctica: the botany of the Antarctic voyage* (1844–1859)	Orchard 1999; CHAH 2015*a*
Henry Charles Andrews	1794–1830	Botanist, botanical illustrator, engraver	*Botanist's Repository* (1779–1812)	Hemsley 1906; CHAH 2007
Robert Kaye Greville	1794–1866	Botanist, botanical illustrator	*Icones Filicum* (1827–1832); *Scottish Cryptogamic Flora* (1822–1826	CHAH 2012
William Henry Harvey	1811–1866	Botanist, algologist, botanical illustrator, lithographer	*Phycologia Australica* (1858–1863)	CHAH 2014*c*; F. Leliaert and O. De Clerck, see http://www.phycology.ugent.be/harvey/, accessed 16 June 2015
William H. Archer	1820–1874	Architect, botanist, botanical illustrator natural-history artist	*Flora Tasmaniae* (1859); *South Australia Illustrated* (1843)	George 2009; CHAH 2015*b*
Angas, George French	1822–1886	Naturalist	*The New Zealanders Illustrated* (1843)	Morgan 1966
Albert Spear Hitchcock	1865–1935	Botanist, botanical illustrator	*A Text-book on Grasses* (1917); *Monographs of* Agrostis (1905) *Leptochloa* (*1903*), *Panicum* (1910) and *Aristida* (1924)	Hunt Institute, see http://huntbotanical.org/art/show.php?5, accessed 16 June 2015
Harry Ardell Allard	1880–1963	Botanist, botanical illustrator		Hunt Institute, see http://huntbotanical.org/art/show.php?1, accessed 16 June 2015
Gilbert Morgan Smith	1885–1959	Botanist, botanical illustrator	*The Fresh-Water Algae of the United States* (1933); *Cryptogamic Botany: Volume I, Algae and Fungi* (1938); *Cryptogamic Botany: Volume II, Bryophytes and Pteridophytes* (1955)	Hunt Institute, see http://huntbotanical.org/art/show.php?7, accessed 16 June 2015
Charles Austin Gardner	1896–1970	Botanist, botanical illustrator	Flora of Western Australia, Gramineae; *Botanical Notes, Kimberley Division of Western Australia* (1923); *Enumeratio Plantarum Australiae Occidentalis* (1930) *Flora of Western Australia Vol. 1, part 1, Gramineae* (1952).; *The toxic plants of Western Australia* (1956); *The vegetation of Western Australia* (1959)	Orchard 1999; Hussey *et al*. 1997; CHAH 2015*c*
Jan Jozua Van Nouhuys	1903–1940	Botanist, botanical illustrator	*Flowering Plants of Africa*	Arnold 2001
Winsome Fanny ('Buddy') Barker	1907–1994	Botanist, botanical illustrator	*Flowering Plants of Africa* (1930-38); *Agapathus* (1965); *Ericas in Southern Africa* (1967)	Arnold 2001

(*continued next page*)

Table 4. (*continued*)

Person	Date	Skills	Area of study and significant publications	Reference
Frederica (Rica) Lucy Erickson	1908–2009	Amateur botanist, author, historian, botanical illustrator	*Orchids of the West* (1951); *Triggerplants* (1958); *Plants of Prey* (1958)	Gooding 1991; Hewson 1999
John Phillip Harrison Acocks (also Acock)	1911–1979	Botanist, botanical illustrator	*Veld Types of Soth Africa* (1953); *Grasses & Pastures of South Africa* (1954)	Arnold 2001
Phoebe Miriam De Vos	1912–present	Botanist, botanical illustrator	*The Genus Romulea in South Africa* (1972)	Arnold 2001
Eily Edith Agnes Gledhill	1914–present	Botanist, botanical illustrator	*Flowering Plants of Africa* (1981); *Eastern Cape Veld Flowers* (1981)	Arnold 2001
Marion Meason ('Maisie')	1914–present	Botanist, botanical illustrator	*Flowering Plants of Africa, the Genera Mesembryanthemaceae* (1971)	Arnold 2001
Jonh Denzil Carr	1916–1997	Botanist, botanical illustrator	*The South African Acacias* (1976); *Combretaceae in Southern Africa* (1987)	Arnold 2001
Brenda Clarke	1917–present	Botanist, botanical illustrator	*The South African Herbal* (1985)	Arnold 2001
Auriol Batten	1918–present	Botanist, botanical illustrator	*Wild Flowers of the Eastern Cape Province* (1966); *Flowers of Southern Africa* (1986); *Dierama* (1991); *Gladiolus of Southern Africa* (1999)	Arnold 2001
Pauline Bohnen	1918–present	Botanist, botanical illustrator	*Flowering Plants of the Southern Cape* (1986) *Bothalia* (1951)	Arnold 2001
Milicent Louie Frean	1927–present	Botanist, botanical illustrator	Senior lecturer in botany at University of the Witwatersrand, Johannesburg	Arnold 2001
Stanley Charles Seagrief	1927–1994	Botanist, botanical illustrator	*The Seaweeds of the Tsitsikama Coastal National Park* (1967)	Arnold 2001
Jane Beatrice Mary Browning	1932–present	Botanist, botanical illustrator	*Southern African Epiphytic Orchids* (1978)' *The Complete Field Guide to Trees of Natal, Zululand & Transkei* (1993)' *Cyperaceae in Natal* (1995)' *Plants of the Okavango Delta: a Field Guide* (1997)	Arnold 2001
Graham Williamson	1932–present	Botanist, botanical illustrator	*The Orchids of South Central Africa* (1977); *Swartkop Nature Reserve* (1993), *Richtersveld National Park* (1995)	Arnold 2001
Frances Esme Hennessy	1933–present	Botanist, botanical illustrator	*South African Erythrinas* (1972); *Orchids of Africa (1981)*; *The Slipper Orchid* (1989)	Arnold 2001
Rosalie Barbara Pike	1933–present	Botanist, botanical illustrator	*Wild Flowers of the Witwatersrand* (1971)	Arnold 2001
Edward George Hudson Oliver	1938–present	Botanist, botanical illustrator	*Erica of Southern Africa* (1967)	Arnold 2001
Helen Hewson	1938–2007	Botanist, author, botanical illustrator	Liverwort family Aneuraceae; *Flora of Australia*	CHAH 2014*d*
Elise Buitendag	1941–present	Botanist, botanical illustrator	*Combretaceae in Southern Africa* (1988)' *The Proteas of Southern Africa* (1982)	Arnold 2001
David Lloyd Jones	1944–present	Nurseryman, orchidologist, author, botanical illustrator	Orchidaceae; *Orchids of Australia (1969)*	CHAH 2002
Margo Lundie Branch	1944–present	Botanist, botanical illustrator	*Trees of Southern Africa* (1977) *The Moraeas of Southern Africa* (1986)	Arnold 2001
Anthony (Tony) E. Orchard	1946–present	Botanist, botanical illustrator	Rosaceae, Haloragaceae, Asteraceae, Rubiaceae *Flora of Australia*	CHAH 2015*d*
Inge Magdelene Oliver	1947–present	Botanist, botanical illustrator	*Flowering Plants of Africa*	Arnold 2001

(*continued next page*)

Table 4. (*continued*)

Person	Date	Skills	Area of study and significant publications	Reference
Allen Lowrie	1948–present	Botanist, botanical illustrator	Stylidiaceae, Droseraceae, carnivorous plants of Australia	CHAH 2013
Jacobus Petrus ('Roos') Roux	1954–present	Botanist, botanical illustrator	*Cape Peninsula Ferns* (1979)	Arnold 2001
Peter Vincent Bruyns	1957–present	Botanist, botanical illustrator	*A Revision of* Microloma (1991); *A Revision of* Hoodia & Lavarania (1993)	Arnold 2001
Pascale Chesselet	1959–present	Botanist, botanical illustrator	Illustrates own research papers on Mesembryanthemaceae	Arnold 2001
John Manning	1962–present	Botanist, botanical illustrator	*Flowering Plants of Africa* (1992); *Gladiolus of Southern Africa* (1999)	Arnold 2001
Nikki Phillips	1965–present	Botanist, botanical illustrator	South African flora	Arnold 2001
Ellen Hickman	1968–present	Botanist, botanical illustrator	*Australian Rushes* (1999)	Gooding 2008
Anne Maclean	1969–present	Botanist, botanical illustrator	South African flora	Arnold 2001

of knowledge acquired by others. Examples of such publications are *Banksias* (Rosser and George 1981, 1988, 2000), *Plants of the Adelaide Plains and Hills* (Dashorst and Jessop 1990) and *The genus* Zantedeschia (Letty 1973). It is worth expanding briefly on the relative roles of the artists and botanists in these publications.

Celia Rosser (1930–present), Monash University Botanical Artist, began the project of painting every *Banksia* L.f. species, as the genus was then understood by Alex George and before the incorporation of *Dryandra* R.Br. (Mast and Thiele 2007). The project took over 25 years to complete, and resulted in the publication of a three-volume monograph entitled *The Banksias* (Rosser and George 1981, 1988, 2000), with accompanying text by Alex George (Blunt and Stearn 1994; Celia Rosser Gallery, *The Banksias*, see http://www.celiarossergallery.com.au/celia-rosser-the-banksia-s.html, accesed 16 June 2015). Celia Rosser was the lead author of these volumes because the main purpose of the work was to publish the paintings.

Gilbert Dashorst (1956–present), an illustrator at the Adelaide Herbarium, led the publication of *Plants of the Adelaide Plains and Hills* (Dashorst and Jessop 1990). It contains colour illustrations by Dashorst of ~1200 species from a range of plant groups, including marine algae, mushrooms, ferns, herbs, sedges and grasses, flowering shrubs and trees. The book has an emphasis on illustrations, with a minimum of technical text by John Jessop (1939–present).

Cythna Letty, one of the most prolific artists of *The Flowering Plants of Africa*, took up the position of botanical artist for the National Herbarium of South Africa in 1927 (Arnold 2001). She taught herself how to use the binocular microscope, to prepare dissections of flowers, and to identify the plant specimens she was illustrating. In this way, she acquired sufficient botanical knowledge to study a plant group of her own choice, which culminated in the illustrated revision of the genus *Zantedeschia* Spreng. published in the journal *Bothalia* (Letty 1973).

In most cases, when the botanist and artist are separate individuals, the botanist instructs the artist in regard to which character traits should be drawn. However, there are examples, documented in the literature, where an artist has observed a character trait before the botanist, or one that the botanist has missed.

An example of an illustrator as an observer and recorder of traits was Franz Bauer, who was highly gifted at using the microscope to record, by illustrations, his observations. In 1802, 120 years after the discovery of the nucleus in animal cells, Bauer did a pencil drawing of the stigma and stigmatic surface of the orchid *Phaius tankervilleae* (L'Her.) Blume, where he observed what were later called 'granular, more opaque greenish yellow specks' (Lack 2016, p. 378), now known to be the nuclei of plant cells. Bauer was obviously unaware of the significance of his discovery. Although this illustration, redrawn by John Lindley (1799–1865), was published in *Illustrations of Orchidaceous Plants* in 1830 (Bauer and Lindley 1838), it was not until Robert Brown's (1773–1858) 1831 paper 'Observations on the organs and mode of fecundation in Orchideae and Asclepiadeae' was read at a meeting of the Linnean Society that the 'specks' were termed by Brown as 'nuclei' (Brown 1831). Brown's paper refers to Bauer's drawing, but does not publish it or acknowledge the discovery. Brown's name is now inseparably connected to the term nucleus, not Bauer's name. This is perfectly acceptable under scientific ethics of 'publish or perish' as it is text that counts, but it may seem a little unfair to the non-scientist (Lack 2016).

In contrast to the above example, the publication of the discovery of a new species from the remote Kimberley region of Western Australia acknowledges the discovery of a unique character trait by the illustrator. During the preparation of the illustrations of *Grevillea donaldiana* Kenneally, Margaret Menadue (1942–present) noticed that the flowers had three tepals, instead of the usual four (Kenneally 1988); Kenneally recorded Menadue's discovery in the paper describing the new species:

> It was during the preparation of the drawings she [Menadue] noted that the flowers were all trimerous [Kenneally 1988, p. 111].

Specimens of the new *Grevillea* were forwarded to Mr D. J. McGillivray (1935–2012) and Mr R. Makinson (1956–

present) of the NSW Herbarium, who were revising *Grevillea* at the time:

> The specific epithet honours Donald J. Gillivray for his contribution to Australian botany and particularly his study of *Grevillea* [Kenneally 1988, p. 117].

Botanical art: a modern role

Given the contemporary focus on molecular phylogenetics in plant systematics, will the important roles of botanical art continue? We argue the affirmative case for complementarity of these disciplines here.

Dictionaries of western European art do not make reference to botanical art or botanical artists, not even some of the greatest, such as Pierre Joseph Redouté (1759–1840; Arnold 2001). The omission is attributed, in part, to botanical art being a hybrid genre of botany as science (function) and botany as visual art (aesthetics). Until the late 1500s, a major function of botanical art was to provide aids for identification of medicinal plants. In the 1600s, an aesthetic revolution saw the flower come into its own, directly as a result of the evolution of the flower garden, to flaunt wealth, display rare plants and the subsequent production of illustrated florilegia to record collections. Such florilegia were early forms of scientific botanical illustration. In contrast to the family portraits of the time that were displayed as an essential part of interior decoration, the portraits of plants in florilegia had limited access, because they were archived in museums and private collections. So, botanical art became confined to the world of science and 'under-researched by art historians, undervalued by art theorists and critics, under-collected by art institutions, and seldom exhibited in art galleries' (Arnold 2001, p. 148).

Today, botanical illustration still sits between the fundamental disciplines of art and science, because science neglects to claim it and art tends to scorn it. Awareness of botanical illustration has been led, in part, by collectors such as Dr Shirley Sherwood (1933–present) and the Hunt Institute, who both collect and exhibit globally. Sherwood, in her book *A Passion for Plants* (Sherwood 2001), comments that despite the popular appeal of botanical illustrations, there have always been those who dismiss such artwork as 'mere illustration'. She goes on to comment that some botanists held the artists in 'low regard', confining them to the back of the herbarium and rarely naming them on papers containing their illustrations. However, in the 21st century, Sherwood noted that there are more galleries showing botanical art, more institutions encouraging artists by buying their work, more classes and more collectors, and it is considered the 'new golden age' of botanical art (Sherwood *et al*. 2005).

Our review has shown that botanical illustration and botanical artists have made an important contribution to botanical science, by helping define taxa, raising awareness of these taxa, reaching a broader audience than just the scientific community, to captivate the viewers' imagination and even alter the viewers' values; however, it has not been specifically determined whether the practice of illustration makes new discoveries.

To examine more critically the contribution of 'discovery through illustration' made by artists it would also be instructive to compare insights found through botanical illustration with knowledge gained through modern scientific techniques, such as molecular genetic analysis. The process of drawing used by botanical illustrators increases the powers of observation and may lead to the discovery of new and possibly neglected traits overlooked by traditional taxonomic techniques. The increased number of characters available to molecular analysis allows for better resolution of taxon delineation, and the hereditability of DNA leads to a better understanding of taxon relationships. Combining the two processes by overlaying traits, identified through the process of illustration, onto well resolved molecular phylogenetic trees, produced by molecular analysis, could identify the morphological traits that the related species have in common, and provide insight into how these traits have evolved through time and as a result of changes in environmental conditions. This is particularly important to conservation biology, where rare and common species may look similar in their 'old' identifying traits. Often these cases are referred to as cryptic species. However, these species may be dissimilar in important but neglected or undetected traits. Better definition of taxa, by keen observations and identification of patterns of morphological change over time, especially in light of climate change, allows for more informed planning of global biodiversity-conservation priorities.

Future research could use a plant family that has a well resolved phylogeny (Hopper *et al*. 2009) and a body of illustrations, such as Haemodoraceae, to explore and hopefully document this concept. The Haemodoraceae is the subject of ongoing study in this respect by the authors.

Conclusions

The present review of botanical illustration and photography has looked at historical context and the contemporary challenges, so as to determine what the role of botanical illustration is in science today, and particularly whether the botanical artist finds new insights for science through the practice of illustration. Cited literature suggested that some botanical artists through history have played an important role in the discovery and description of plant diversity. The artists' contributions are not always explicitly described, but are inferred by artistic participation, and in the publication of artwork. Artists have been essential members of voyages of botanical exploration, where they have accurately recorded morphological character traits critical for recognising and identifying species. Their artwork has been published widely. The contribution of artists varies. Some have been both scientists and artists, whereas others have been solely artists working collaboratively with scientists. The nature of this relationship affects the degree of recognition the artists receive. It is possible that where the contribution of an artist has been insightful, they may have been recognised by the scientists naming species in their honour.

This review has shown that, in many instances, photographs are increasingly being used in preference to illustrations in the scientific literature. The reasons for this are not clear, but they could be a combination of cost, editorial preference, author preference or the relative advantages of one image type over another in depicting particular traits, or modern costs for

publishing colour work. Despite the expanded role of photographs, they have not usurped the place of botanical illustrations in the scientific literature, instead the two image types are often used in combination, playing complementary roles. The camera has also become an important tool in the contemporary botanical artist's kit. Whether botanical illustration has a purpose, other than depiction of particular plant traits, such as the increased powers of observation gained through the process of illustration, and whether this leads to new discoveries regarding plant traits, has not been resolved and requires further research.

Conflicts of interest

The authors declare that they have no conflicts of interest.

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