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A revised area taxonomy of phytogeographical regions within the Australian Bioregionalisation Atlas

MALTE C. EBACH[1,*], DANIEL J. MURPHY[2], CARLOS E. GONZÁLEZ-OROZCO[3] & JOSEPH T. MILLER[4,5]
[1] *School of Biological Earth and Environmental Sciences, UNSW, Kensington, NSW 2052, Australia.*
[2] *National Herbarium of Victoria, Royal Botanic Gardens Melbourne, Birdwood Avenue, South Yarra, VIC 3141, Australia.*
[3] *Institute for Applied Ecology and Collaborative Research Network for Murray-Darling Basin Futures, University of Canberra, ACT 2601, Australia.*
[4] *Centre for Australian National Biodiversity Research, CSIRO Plant Industry, GPO Box 1600, Canberra, ACT 2601, Australia.*
[5] *Division of Environmental Biology, National Science Foundation, Arlington, Virginia 22230 USA.*
**Corresponding author, Malte C. Ebach: mcebach@gmail.com.*

Abstract

The phytogeographical regions and sub-regions of Australia are revised in light of new data from a recent analysis by González-Orozco, Ebach *et al.* (2014). The new revision includes two new regions, Northern *regio nova* and Northern Desert *regio nova,* and five new sub-regions, Nullarbor *sub-regio nova,* Central Desert *sub-regio nova,* Great Sandy Desert Interzone *sub-regio nova*, Central Queensland *sub-regio nova* and, Southwestern *sub-regio nova*. This new revised version of the phytogeographical regions and sub-regions of Australia's land plants provides an updated classification based on historical nomenclature. The analysis by González-Orozco, Ebach *et al.* (2014) is a biogeographically centered classification that generated the first exclusively taxonomic regionalisation of Australia's land plants, used here to update the ABA phytogeographical regions.

Key words: area nomenclature, Central Desert, Central Queensland, Great Sandy Desert Interzone Northern, Northern Desert, Nullarbor, Southwestern

Introduction

Australian phytogeographical regionalisation has its beginnings in the work of Ferdinand Mueller (1825–1896), who served as the Victorian Government botanist for over 40 years (Home 1995). Mueller was the first to propose a regionalisation for the Australian vegetation, which he divided into seven groups "Plants of the dense coast-forests [...] the Brigalow scrub [...] the open downs [...] the desert [...] the sandstone table-land [...] the sea-coast [and;] the banks and valleys of rivers" (Mueller 1858: 146).

Since Mueller, there have been several different area taxonomies that may be classified into three distinct groups: vegetations (e.g., Mueller 1858; Diels 1906; Beard 2001), biomes (Byrne *et al.* 2008), and taxonomic/endemic areas or bioregions (Tate 1889, Burbidge 1960, Crisp *et al.* 1995; 1999; Ladiges *et al.* 2011 González-Orozco *et al.* 2011, 2013, González-Orozco, Ebach *et al.* 2014, González-Orozco, Thornhill *et al.* 2014; Stevenson *et al.* 2012; see Ebach 2012 for a detailed history). Of these, the bioregions are of interest as they pertain purely to taxonomic distributions and endemism, which can be quantified independently to other data such as climate and topography using spatial analysis (e.g., Laffan *et al.* 2010). A recent study by González-Orozco, Ebach *et al.* (2014) has used taxonomic distributions to test existing phytogeographical areas, which have been classified into six regions within the *Australian Bioregionalisation Atlas* (ABA, Ebach *et al.* 2013). The study by González-Orozco, Ebach *et al.* (2014) used a diverse set of major land plant groups including bryophytes, ferns and several of the largest angiosperm genera and families in Australia (Table 1). The analysis revealed a 65% overlap between their six phytogeographical regions and those of the ABA regions. González-Orozco, Ebach *et al.* (2014), however, established that the analysis had also resolved evidence for smaller sub-regions and provinces that were not formally described in Ebach *et al.* (2013); these will be defined and described here.

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TABLE 1. The plant groups used in González-Orozco, Ebach *et al.* (2014) and applied to generate the new ABA revision, with number of species per taxonomic group.

Taxon name	Number of species
Acacia	1,020
Asteraceae	823
Eucalypts (*Angophora*, *Corymbia* & *Eucalyptus*)	791
Ferns	356
Hornworts	13
Liverworts	735
Melaleuca	282
Mosses	835
Orchids	1,188
TOTAL	6,043

The aim of this study is to revise the existing phytogeographical regions and sub-regions, and identify novel phytoregions for inclusion within the ABA, in order to provide an up-to-date and quantifiable area taxonomy. The revised area taxonomy provides an explicit list of area definitions and a standardised nomenclature based on the *International Code of Area Nomenclature* (ICAN, Ebach *et al.* 2008), an international area naming system for biogeographical areas (areas of endemism) that is used across a range of areas and taxonomic groups: fishes (Albert & Reis 2011; López *et al.* 2008; Lumbantobing 2010), mammals (Escalante *et al.* 2013), Lepidoptera (Costa *et al.* 2013), gastropods (Neubauer *et al.* 2015), floristic regions (Van Rooy & Van Wyk 2010; Postigo Mijarra *et al.* 2009), and continental bioregionalisation (Ebach *et al.* 2013, Morrone 2014, 2015a,b).

The area taxonomy presented herein is provisional and is open to further revision, allowing for a transparent area classification system that is similar to Linnaean taxonomy and rules of nomenclature used for biological organisms. Because an area taxonomy is analogous to biological taxonomy, in that areas are defined by their biotic distributions in the same way as biological characters are used to define taxa, like a taxonomy, new discoveries may require re-assessment and possible taxonomic revision. For instance, if we discover that a region is non-monophyletic, a revision may be necessary. Alternatively, if we find reliable evidence that a geographical structure, such as a fault zone or mountain range acts as a barrier to many different taxa within a region, we may need to describe new sub-regions. Area taxonomy, like its analog in biological classification, is an on-going research program requiring ongoing revision and updates as more data come to hand. The validity, range and synonymy of Australasian regions and sub-regions will be continually debated. Our area taxonomy herein is not the final word, but a way of providing comparable biogeographic areas for communication and, hopefully provoking discussion and driving future research on Australasian area taxonomy.

Area taxonomy of Australia's phytogeographical regions

The recently released ABA incorporates all significant taxonomic regionalisations since Tate (1889). Regionalisation based on vegetation (Beard 2001), ecosystems (Olson *et al.* 2001) or a mixture of geographical and distributional data (Heap *et al.* 2005) have been omitted from this area taxonomy, as they are difficult to quantify. The reason phytogeographical areas are needed is that no two ecosystems, vegetation types or medley of geographical and distribution data are equally comparable, as early 19th century plant geographers have lamented (Nelson 1978). For instance, elevation, climate (i.e., rainfall, solar radiation, evaporation) vegetation, and surface geology are different for each area and therefore incomparable. However, they can be used to find correlations between distributions and the causes of distribution, such as biotic breaks (see Di Virgilio *et al.* 2012, 2013). Presently two large bioregionalisation efforts, the *Interim Biogeographic Regionalisation for Australia* (IBRA) and *National Marine Bioregionalisation of Australia* (NMBA), are preferred choices for conservation biogeographers, as they are precisely geographically defined and map-based. Unlike the ABA, both IBRA and NMBA comprise a medley of different types of datasets, which together may create areas that are variously defined by topography or drainage basins, rather than taxic distribution. Since users are unable to establish what explicitly defines each of the ABA areas, and how these data

sets are correlated, they pose a problem of dependent data. The ABA, which is based mostly on taxic distributions, is herein revised to include phytogeographical regions and sub-regions based on taxic distributional overlap of a number of diverse plant taxa (González-Orozco, Ebach *et al.* 2014). In order to compare two biogeographical areas equally, they need to be as independent as possible, but sharing a common variable, in this case taxonomic distribution of the flora. As an independent form of data, distributional data of taxa are useful for delimiting geographical areas for biogeographical historical analyses (i.e., cladistic biogeography, phylogeography etc.).

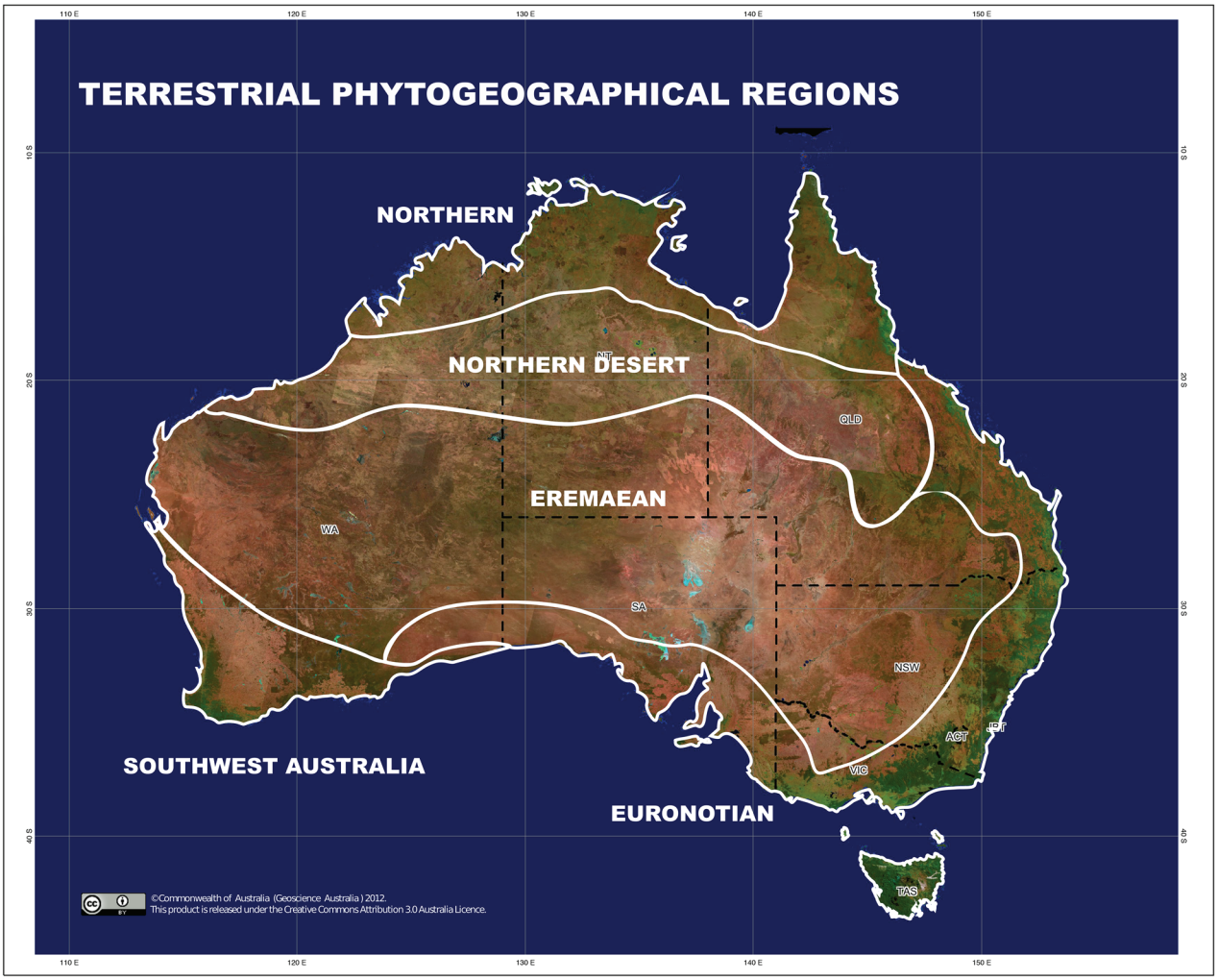

FIGURE 1. The five ABA phytogeographical sub-regions for Australia's land plants based on the raw data in González-Orozco, Ebach *et al.* (2014). The areas are an approximation of the 100km2 grid cells in González-Orozco, Ebach *et al.* (2014). As these areas are defined on a numerical approach (like that in the IBRA classification), their monophyly is still unknown.

The ABA is a resource that is aimed at biogeographers who require precise, delimited areas to perform biogeographic analyses. The area taxonomic revision herein is based primarily on a recent study by González-Orozco, Ebach *et al.* (2014), which used 750,741 geo-referenced herbarium records containing 6,043 species that correspond to six widely distributed vascular plant groups and three non-vascular plant groups (Table 1). In order to quantify the phytogeographical regions, they used the rate of change in species composition between sites, 'species turnover', calculated as Simpson's beta (Tuomisto 2010). González-Orozco, Ebach *et al.* (2014) uncovered areas that overlapped with existing formally named regions and sub-regions in the ABA. Given that this is the first such analysis conducted, the high percentage in overlap indicates the ingenuity of past phytogeographers.

This new revision includes 5 regions (Figures 1 & 2) and 21 sub-regions (Figures 3 & 4; Table 2). The last revision by Ebach *et al.* (2013), which was a summary of published phytoregionalisations, had 17 sub-regions, and many areas within the Australian continent that were unnamed or simply left as gaps, due to uncertainty surrounding their boundaries or the lack of pre-existing definitions based on taxic distributions. As such these gaps were a remnant of studies by Cracraft (1991) and Crisp *et al.* (1995), who wanted to outline areas of endemism, leaving suspected areas of overlap blank. While these classifications were an excellent first step and highlighted unique areas of endemism,

they failed to address the needs of biogeographers when taxa were distributed outside these areas of endemism. The new revision herein has extended these areas so there are no currently no gaps for areas within Australia.

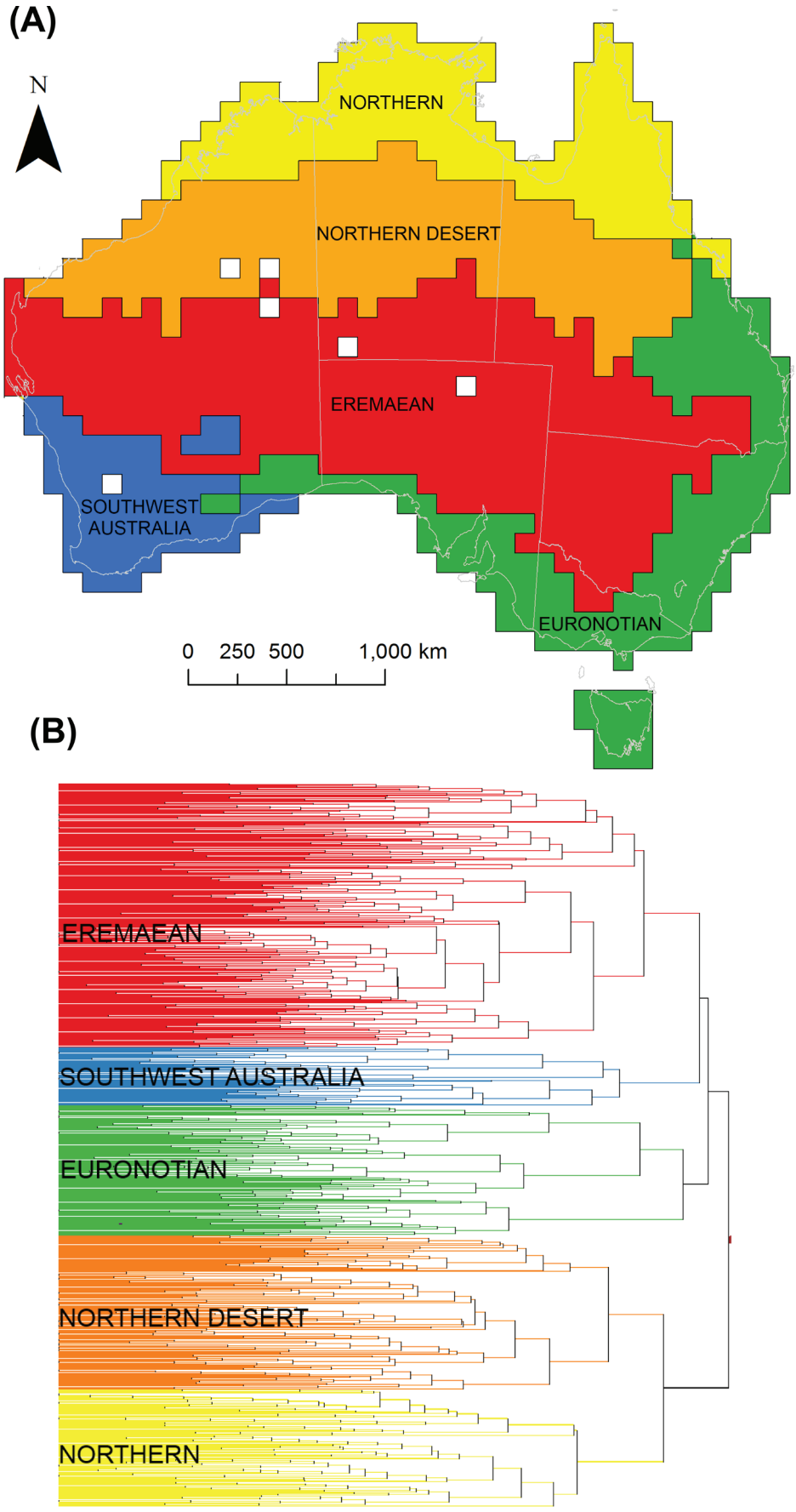

FIGURE 2. A. The raw data from the González-Orozco, Ebach *et al.* (2014) analysis. **B.** Corresponding dendrogram that shows the geographic clustering based on species turnover.

The nomenclature herein follows the ICAN (Ebach *et al.* 2008), in which area names are designated a type locality and diagnosis and can be synonymised. The ICAN is vital for preserving names and preventing multiple names from having different definitions. The ICAN is used throughout the ABA. New regions are designated as *regio nova* and new sub-regions as *sub-regio nova*.

TABLE 2. A list of the five Australian phytogeographical regions and twenty-one sub-regions, several that are proposed herein.

TERRESTRIAL PHYTOGEOGRAPHICAL REGIONS		
Sub-Realm	Region	Sub-Region
Australia	Northern Australia *regio nova*	Southern New Guinea *sub-regio nova*
		Cape York Peninsula Cracraft 1991
		Arnhem Land Cracraft 1991
		Kimberley Plateau Cracraft 1991
	Euronotian Tate 1889	Atherton Cracraft 1991
		Eastern Queensland Crisp *et al.* 1995
		Southeastern Crisp *et al.* 1995
		Victoria Crisp *et al.* 1995
		Tasmania Cracraft 1991
		Adelaide Cracraft 1991
		Eyre Peninsula Cracraft 1991
		Nullarbor *sub-regio nova*
	Eremean Tate 1889	Western Desert Cracraft 1991
		Eastern Desert Cracraft 1991
		Pilbara Cracraft 1991
	Northern Desert Cracraft 1991	Central Desert *sub-regio nova*
		Great Sandy Desert Interzone *sub-regio nova*
		Central Queensland *sub-regio nova*
	Southwest Australia Diels 1906	Southwestern *sub-regio nova*
		Southwest Interzone Ladiges *et al.* 2005
		Hampton Ladiges *et al.* 2005

Nomenclatural Note

The ICAN states: "A name that has been synonymised is bracketed" (Sec. C. Art. 3.3). While in previous area taxonomies this has been interpreted to mean the authors name, it is herein interpreted to mean the area name and the author's name.

Area Taxonomy

Kingdom AUSTRAL Engler 1899

Austral Engler 1899: 149
Austral Morrone 2002: 150
Austral Morrone 2015a (in press)

Diagnosis. The Austral kingdom "corresponds to the southern temperate areas, in South America, South Africa, Australasia and Antarctica" (Morrone 2015a in press).

Remarks. In his recent reappraisal of the biogeographical regionalization of the world, Morrone (2015a) cites Engler (1899) as the first usage of the term "Austral" in his phytogeographic regionalisation of the world, which is

adopted in this classification. The Austral of Morrone, (2002, 2015a) is identical to that of Engler (1899). See Morrone (2015a) for a full account of the area taxonomy of the Austral kingdom.

Realm AUSTRALIA de Candolle 1820

(*La Nouvelle-Hollande* de Candolle 1820: 411)
Australia Good 1964: 32
(*Australian Kingdom* Doing 1970: 84–85, Map)
(*Australian Realm* Udvardy 1975: 36)

Diagnosis. The continent of Australia, including New Guinea south of the Central Range.

Type-locality. Lake Eyre, South Australia, Australia, 28°10'30.04"S 137°17'32.60"E.

Remarks. See Ebach *et al.* (2013).

Region NORTHERN AUSTRALIA *regio nova*

(*Euronotian* [in part] Tate 1889: 315)
(Fig. 1)

Diagnosis. Northern Australia between Broome in Western Australia and Mackay in Queensland, including the area north of the Great Sandy and Tanami deserts and Barkly Tableland.

Type-locality. Nourlangie Rock, Kakadu, Northern Territory, Australia, 12°52'1.10"S 132°48'40.14"E.

Remarks. Originally part of the Euronotian (Tate 1889), the Northern region is defined by a recent analysis by González-Orozco, Ebach *et al.* (2014), in which the northern part of the Euronotian was separated as an unrelated region. Given that it has greater biotic and taxonomic affinities with the Eremaean, it has been placed into its own region. Bowman *et al.* (2010) recovered a similar area, which they refer to as the Australian Monsoonal Tropical biome (AMT). The AMT is a region of fragmented smaller areas that are separated by larger biogeographical barriers. We feel that the AMT is a better fit within the Terrestrial Ecoregions of the World (Olsen *et al.* 2001), as the biome is based on climate and vegetation and habitat types. Each of the smaller areas is synonymised within the sub-regions of the Northern Australia region.

Sub-regions included. New Guinea Doing 1970, Cape York Peninsula Cracraft 1991, Arnhem Land Cracraft 1991, and Kimberley Plateau Cracraft 1991.

Sub-region SOUTHERN NEW GUINEA *sub-regio nova*

(*New Guinea* [in part] Doing 1970: 84–85, Map)
(*New Guinea* Crisp *et al.* 1995: 459)
(*Trans-Fly Plains* Bowman *et al.* 2010: 203)

Diagnosis. New Guinea, including Papua New Guinea and Irian Jaya, south of the Central Range.

Type-locality. Lake Murray, near Zarit, Papua New Guinea, 6°52'44.76"S 141°31'15.15"E.

Remarks. New Guinea was described by Crisp *et al.* (1995) as "actually southern New Guinea, mainly the monsoonal region; none of the taxa included in this study extend to the highlands, and only Embothriinae (*Albxylon brachycarpum*) occur in rainforest" (Crisp *et al.* 1995: 459). The name has been changed to Southern New Guinea, as the original designation and map by Crisp *et al.* (1995) do not include much of the area south of the Central Range.

Sub-region CAPE YORK PENINSULA Cracraft 1991
(Fig. 3)

Cape York Peninsula Cracraft 1991: 213
(*Cape York Peninsula* Bowman *et al.* 2010: 203)

Emended diagnosis. The area lying north between Cooktown and Hughenden, Queensland, extends west toward the Leichhardt and Nicholson Rivers in Queensland.

Type-locality. McIlwraith Range, Coen, Queensland, Australia, 13°46'27.00"S 143°19'18.00"E.

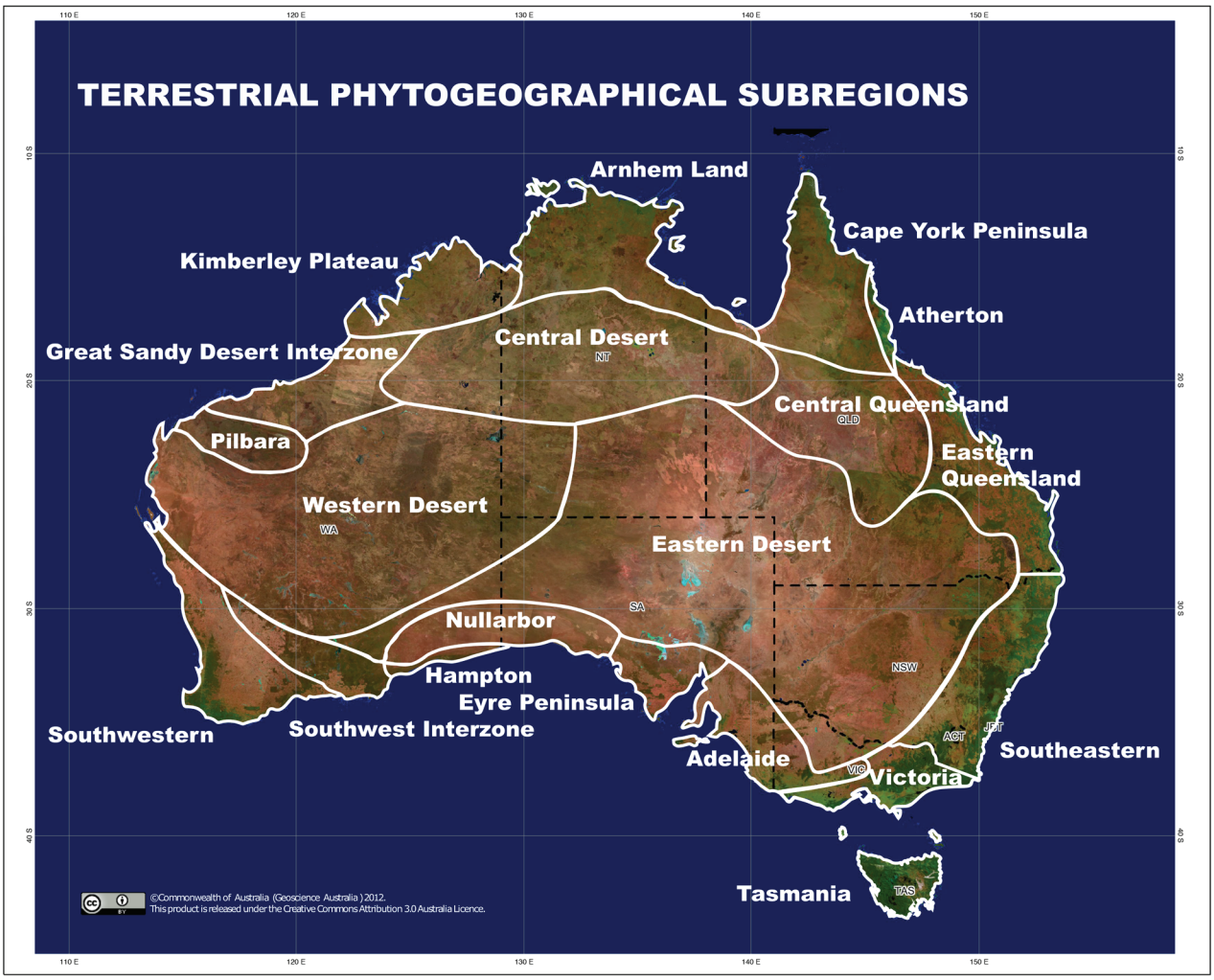

FIGURE 3. The twenty ABA phytogeographical sub-regions for Australia's land plants (excluding Southern New Guinea). The areas are an approximation of the 100km2 grid cells in González-Orozco, Ebach *et al.* (2014). As these areas are defined on a numerical approach (like that in the IBRA classification), their monophyly is still unknown. Southern New Guinea is not figured.

Remarks. Cape York Peninsula has been extended south toward the southwestern end of the Great Dividing Range between Hughenden and Cloncurry, Queensland. The sub-region extends northwest towards the Leichhardt and Nicholson Rivers in Queensland. The analysis by González-Orozco, Ebach *et al.* (2014) shows that the Leichhardt and Nicholson Rivers may form an overlap zone between the Cape York and Arnhem Land sub-regions.

Sub-region ARNHEM LAND Cracraft 1991
(Fig. 3)

Arnhem Land Cracraft 1991: 213
(*Arnhem* Crisp *et al.* 1995: 460)
(*Top End* [in part] Bowman *et al.* 2010: 203)
(*Top End* [in part] Ladiges *et al.* 2011: 33)
Arnhem Land Ebach *et al.* 2013: 322

Emended diagnosis. The area west of the Leichhardt and Nicholson Rivers in Queensland, extending north between Carpentaria, Queensland to the Chamberlain River and Cambridge Gulf in Western Australia.

Type-locality. Nourlangie Rock, Kakadu, Northern Territory, Australia, 12°52'1.10"S 132°48'40.14"E.

Remarks. Ladiges *et al.* (2011) provided a concise definition for Cracraft's Arnhem Land, however we confine its eastern range to Lake Woods, Northern Territory, slightly altering the definition of Ladiges *et al.* (2011), which extends considerably to the southeast.

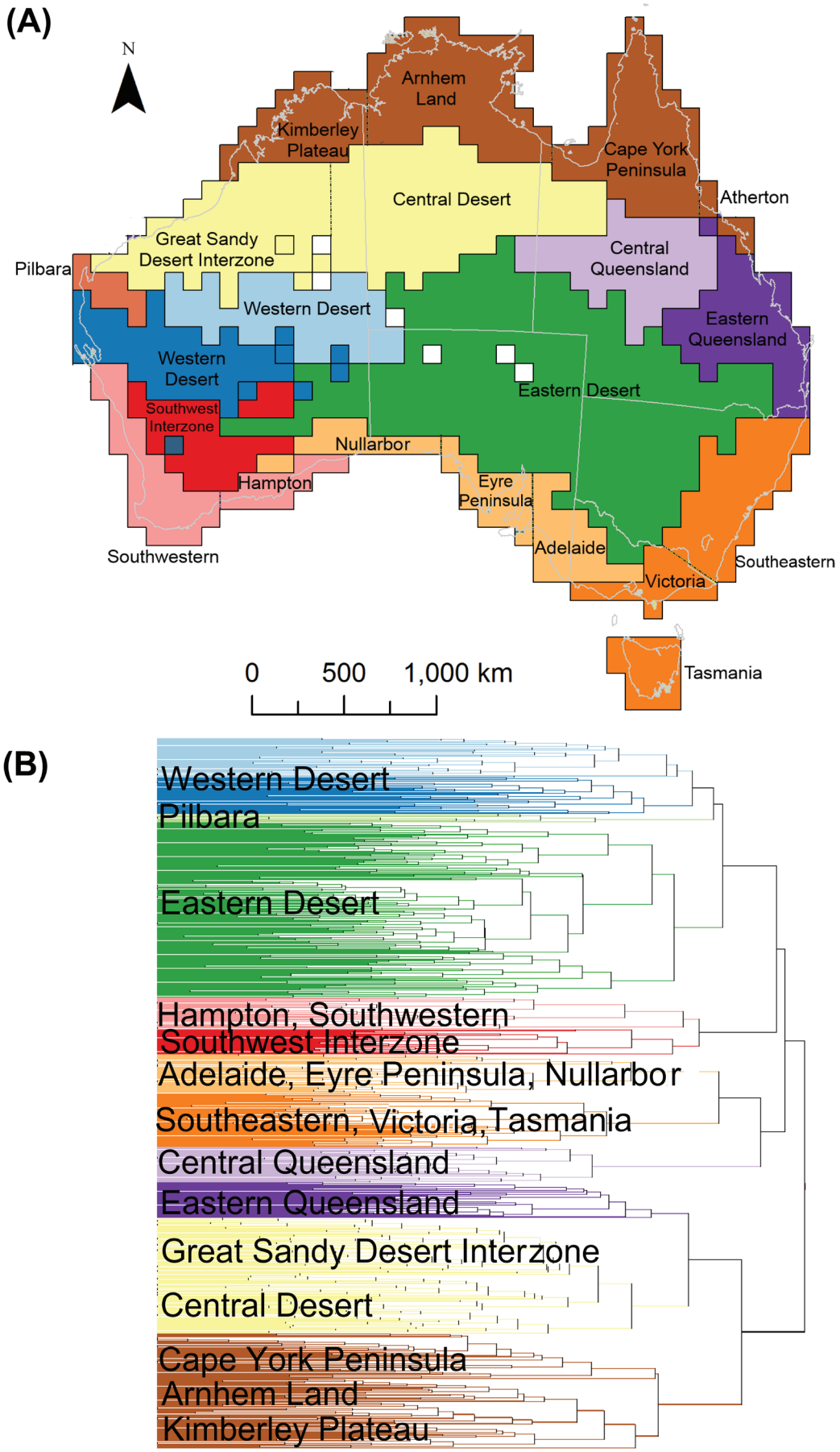

FIGURE 4. A. The raw data from the González-Orozco, Ebach *et al.* (2014) analysis. **B.** Corresponding dendrogram that shows the geographical clustering based on species turnover.

Sub-region KIMBERLEY PLATEAU Cracraft 1991
(Fig. 3)

Kimberley Plateau Cracraft 1991: 213)
(*Kimberley* Crisp *et al.* 1995: 460)
(*Kimberley* Bowman *et al.* 2010: 203)
(*Kimberley* Ladiges *et al.* 2011: 33)

Emended diagnosis. The area east of the Chamberlain River extending as far south as the Fitzroy River, extending as far west as Broome, Western Australia.

Type-locality. Mitchell Plateau Western Australia, Australia, 15° 7'14.27"S 125°47'39.67"E.

Remarks. The emended diagnosis follows Ladiges *et al.* (2011) in part, with the western most area bounded by Broome.

Region EURONOTIAN Tate 1889
(Fig. 1)

Euronotian Tate 1889: 315)
(*East Australia* Diels 1906: 38–39)
Euronotian Ebach *et al.* 2013: 319

Emended diagnosis. The Great Dividing Range and eastern lowlands and coastal areas between the Grampians and the Border Ranges.

Type-locality. Mount Hay, Blue Mountains National Park, NSW, Australia, 33°37'16.43"S 150°24'38.89"E.

Remarks. Tate (1889) defined the Euronotian as being "dominant in the south and east parts of the Continent" (Tate 1889: 315), which he extended in his Rain Map to include northern and northwestern Australia. Ebach *et al.* (2013) revised Tate's region to include the Kimberly, Arnhem Land and Cape York sub-regions. However, analysis by González-Orozco, Ebach *et al.* (2014) has shown that the definition of the Euronotian is aphyletic and consisted of parts of three distinct regions (Northern, Eastern Queensland and Euronotian). The Euronotian has been preserved as a senior synonym according to the ICAN and extended towards the southwest to match the description of Tate (1889). The Euronotian now includes Adelaide Cracraft 1991, Eyre Peninsula Cracraft 1991 and Hampton Ladiges *et al.* 2011, which were formerly part of the Eremaean Tate 1889.

Sub-regions Included. Atherton Cracraft 1991, Crisp *et al.* 1995, Eastern Queensland Crisp *et al.* 1995, Southeastern NSW Crisp *et al.* 1995, Victoria Crisp *et al.* 1995, Tasmania Cracraft 1991, Adelaide Cracraft 1991, Eyre Peninsula Cracraft 1991 and, Nullarbor *sub-regio nova*.

Sub-region ATHERTON Cracraft 1991
(Fig. 3)

Atherton Cracraft 1991: 213
Atherton Crisp *et al.* 1995: 459
(*Queensland Wet Tropics* Ladiges *et al.* 2011: 33)

Diagnosis. See Cracraft (1991).

Type-locality. Mount Hypipamee, Mount Hypipamee National Park, Queensland, Australia, 17°25'28.84"S 145°28'59.40"E.

Sub-region EASTERN QUEENSLAND Crisp *et al.* 1995
(Fig. 3)

Eastern Queensland Crisp *et al.* 1995: 459
(*Coast East Queensland* Ladiges *et al.* 2011: 34)
(*Inland South East Queensland* Ladiges *et al.* 2011: 33–34)
(*Inland Central Queensland* Ladiges *et al.* 2011: 33)
(*Inland North Queensland* Ladiges *et al.* 2011: 33)
Eastern Queensland Ebach *et al.* 2013: 321

Emended diagnosis. The Great Dividing Range between the Border Ranges (NSW-QLD border) and the Burdekin River, Queensland including all low lying and coastal areas to the east.

Type-locality. Mount Molangul, Gindoran Queensland, Australia, 24°40'3.00"S 151°31'39.00"E.

Remarks. Ebach *et al.* (2013) have extended the sub-region to include the western margin of the Great Divide. A recent analysis by González-Orozco, Ebach *et al.* (2014) recovered an area (Central-eastern) that like Eastern Queensland overlaps topographically with the Great Dividing Range, extending as far west as Charleville, Queensland.

Sub-region SOUTHEASTERN Cracraft 1991
(Fig. 3)

(*Southeastern Forest* Cracraft 1991: 214)
(*Southeastern New South Wales* Crisp *et al.* 1995: 459)
(*South East New South Wales* Ladiges *et al.* 2011: 34)

Diagnosis. The area between the NSW-Victorian border following the western margin of the Great Dividing Range up to the NSW-QLD border.

Type-locality. Kurnell, Sydney, NSW, Australia, 34° 0'23.79"S 151°12'59.83"E.

Remarks. Crisp *et al.* (1995) proposed Southeastern NSW and Victoria as two new phytogeographical areas derived from Cracraft's Southeastern Forest region. The analysis by González-Orozco, Ebach *et al.* (2014), has recovered both of Cracraft's areas proposed by Crisp *et al.* (1995), which extend westward to the western extremities of the Great Dividing Range. The southern and northern boundaries remain the same, with the southern-most boundary found further inland near Albury. Di Virgilio *et al.* (2013), however did find an east-west break in the Bermagui area in NSW, about 140 kms further north than the boundary proposed by Crisp *et al.* (1995). As the western part of the boundary proposed by Di Virgilio *et al.* (2013) is delimited by the eastern extent of the Great Divide, it may constitute a provincial break within the Southeastern sub-region. Given that Cracraft's original name has precedence, Southeastern New South Wales is herein a subjective synonym of Southeastern Forest. The term "forest" has been omitted as it incorrectly describes the area in question.

Sub-region VICTORIA Crisp *et al.* 1995
(Fig. 3.)

Victoria Crisp *et al.* 1995: 460

Emended diagnosis. The area between the NSW-Victorian border to areas lying south between Mount Gambier, South Australia and Melbourne, following the western margin of the Great Dividing Range up to the NSW-QLD border.

Type locality. Otway Ranges, Victoria, Australia, 38°40'0.00"S 143°34'60.00"E.

Remarks. The analysis by González-Orozco, Ebach *et al.* (2014) is far more detailed as to where the Victorian sub-region ends and where the Adelaide sub-region beings. Crisp *et al.* (1995) who proposed the area Victoria were vague as to the actual extent of the region.

Sub-region TASMANIA Cracraft 1991
(Fig. 3)

Tasmania Cracraft 1991: 214
Tasmania Crisp *et al.* 1995: 460

Diagnosis. The area including Tasmania and the Bass Strait Islands.

Type-locality. Cradle Mountain Tasmania, Australia, 41°41'6.48"S 145°57'9.55"E.

Remarks. González-Orozco, Ebach *et al.* (2014) identified Tasmania as linked to the southern coast of Victoria in their analysis. However, Crisp *et al.* (1995) have made a case for keeping Tasmania as a separate sub-region based on cladistic biogeographical analysis, and while Burbidge (1960) considered the Tasmanian flora "not highly endemic at the generic level" (Burbidge 1960: 76), that author still separated it as an area (i.e., Tasmanian focal area). Given this, and until further results to the contrary we have retained Tasmania as a separate sub-region in the present area taxonomy.

Sub-region ADELAIDE Cracraft 1991
(Fig. 3)

Adelaide Cracraft 1991: 214
Adelaide Crisp *et al.* 1995: 460

Emended diagnosis. The areas south between Port Augusta and the Murray River at the South Australian Victorian border (including Kangaroo Island), with an eastern extension to the north of Melbourne, Victoria, including the areas between Mount Gambier, South Australia and Melbourne.

Type-locality. Gluepot Reserve, South Australia, Australia, 33°45'42.52"S 140° 7'27.51"E.

Remarks. González-Orozco, Ebach *et al.* (2014) recovered a large area within the Euronotian, including much of Adelaide and Eyre Peninsula. The area overlaps considerably with Cracraft's Adelaide and Eyre Peninsula Sub-regions, with the exception of the northern most extremities in the former. The Adelaide sub-region extends much farther east than Cracraft's original diagnosis, almost segregating western Victoria (including the Grampians and the Otways) from the Victoria Sub-region.

Sub-region EYRE PENINSULA Cracraft 1991
(Fig. 3)

Eyre Peninsula Cracraft 1991: 214
(*Eyre* Crisp *et al.* 1995: 460.)

Emended diagnosis. All areas south between Port Augusta and Ceduna, South Australia extending as far north as Lake Gairdner.

Type-locality. Darke Peak Range, South Australia, Australia, 33°28'26.85"S 136°10'29.68"E.

Remarks. The Eyre Peninsula Sub-region differs from Cracraft's original area in that it extends farther west to Ceduna, South Australia.

Sub-region NULLARBOR *sub-regio nova*
(Fig. 3)

Diagnosis. The area incorporating the Nullarbor Plain, bounded in the east by Ceduna, South Australia, and in the west by the Yilgarn Craton and in the north by the southern edge of the Great Victoria Desert.

Type-locality. Forrest Railway Station, Western Australia, Australia, 30°51'03.34"S 128°06' 11.31"E.

Remarks. Previously part of the Eremaean region, the Nullabor sub-region has been found by González-Orozco, Ebach *et al.* (2014) to have closer affinities with areas in the Euronotian, as opposed to the Southwest region. The same analysis has also shown that areas to the south, such as Hampton and Esperance are more closely related to the Southwest region. However, until a biogeographical analysis is undertaken, the relationships between sub-regions are hypothetical.

Region EREMAEAN Tate 1889
(Fig. 1)

(*Eremian* Tate 1889: 315)
Eremaean Diels 1906: 40
(*Central or Eremaean* Takhtajan 1986: 274)
(*Eremaean* [in part] Ebach *et al.* (2013): 322)

Emended diagnosis. The semi-arid to dry desert region bounded by the Euronotian region to the south east, Eastern Queensland region to the east, the Southwest region in the west and the Northern region to the north.

Type-locality. Lake Eyre, South Australia, Australia, 28°10'30.04"S 137°17'32.60"E.

Remarks. The Eremaean region formerly included all semi-arid to desert areas bounded by the Southwest and Euronotian regions. However, González-Orozco, Ebach *et al.* (2014) have discovered that there is a distinct division between the north and south of this region, the south sharing greater affinities with the Southwest region and the

Northern Desert sharing greater affinity with the Northern region. In order to preserve the name, the Eremaean region is restricted to the south where the type locality Lake Eyre is found.

Sub-regions Included. Western Desert (Cracraft 1991) and Eastern Desert (Cracraft 1991).

Sub-region WESTERN DESERT Cracraft 1991
(Fig. 3)

Western Desert Cracraft 1991: 214
Western Desert Crisp *et al.* 1995: 460
(*Southern Desert* Ladiges *et al.* 2011: 33)
(*Central Desert* Ladiges *et al.* 2011: 32–33)
(*Pilbara* [in part] Cracraft 1991: 214)
(*Pilbara* [in part] Crisp *et al.* 1995: 460)

Emended diagnosis. A semi-arid to desert area extending in the south from Shark Bay to Kalgoorlie in Western Australia to the Petermann Ranges in northwestern South Australia and Northern Territory. In the north extending from the Petermann Ranges to Lake Dennis and Exmouth in Western Australia.

Type-locality. Veevers Crater, Western Australia, 22°58′12 S, 125°22′21″E.

Remarks. The Western Desert sub-region has been extended further west to include the southern part of the Pilbara sub-region Cracraft 1991 based on the geo-spatial analysis by González-Orozco, Ebach *et al.* (2014). In addition, the Western Desert has been restricted in latitude, with the former northern boundary in line with Lake Dennis and Exmouth.

Sub-region EASTERN DESERT Cracraft 1991
(Fig. 2, 3)

Eastern Desert Cracraft 1991: 214
Eastern Desert Crisp *et al.* 1995: 460
(*Pilbara* [in part] Cracraft 1991: 214)
(*Pilbara* [in part] Crisp *et al.* 1995: 460)

Emended diagnosis. The area bounded by the Southwest Australian and Euronotian in the south and southeast respectively, and Eastern Queensland in the east. The northern boundary extends from the western part of the Great Dividing Range near Longreach, Queensland to the Dulcie Ranges in the Northern Territory, to the Petermann Ranges. The Western boundary extends into Western Australia as far as Kalgoolie.

Type-locality. Nappa Merrie Breakaways, Queensland, Australia, 27°23’7.24”S 141° 9’51.81”E.

Remarks. The Eastern Desert is extended much farther west, south and southeast since it was first proposed by Cracraft (1991). Like the Western Desert, its northern extent has been reduced based on the findings of González-Orozco, Ebach *et al.* (2014).

Sub-region PILBARA Cracraft 1991
(Fig. 3)

Pilbara Cracraft 1991: 214
Pilbara Crisp *et al.* 1995: 460

Emended diagnosis. The area covering the Hamersley Ranges.

Remarks. Cracraft (1991) correctly diagnosed the Pilbara as the “uplands of the Pilbara (Hamersley Plateau)” (Cracraft 1991: 214) However, Cracraft included some parts of the Great Sandy desert bounded “to the west by the Gibson Desert, and to the south by lowlands” (Cracraft 1991: 214). The embedded diagnosis clarifies that the sub-region is restricted to the area covering the Hamersley Ranges.

Region NORTHERN DESERT Cracraft 1991
(Fig. 1)

Northern Desert Cracraft 1991: 214
(*Pilbara* [in part] Cracraft 1991: 214)
(*Eastern Desert* [in part] Cracraft 1991: 214)
(*Northern Desert* Crisp *et al.* 1995: 460)
(*Pilbara* [in part] Crisp *et al.* 1995: 460)
(*Eastern Desert* [in part] Crisp *et al.* 1995: 460)
(*Northern Desert* Ladiges *et al.* 2011: 32)

Diagnosis. Bounded by the Kimberley and Arnhem Land sub-regions of the Northern region in the north, extending as far south as Port Headland in Western Australia, across to Longreach, Queensland in the east, where it is bounded by the Eremaean and Eastern Queensland regions.

Type-locality. Mount Singleton, Northern Territory, 21°55'27.59"S 130°45'57.39"E.

Remarks. Ebach *et al.* (2013) had originally chosen Riversleigh, Queensland as the type locality for the Northern Desert. Riversleigh is, however, situated in the Eastern Desert sub-region, indicating that the Northern Desert sub-region is a synonym of the Eastern Desert. Given the error in Ebach *et al.* (2013), we retain the Northern Desert and assign a new type, Mount Singleton, Northern Territory.

González-Orozco, Ebach *et al.* (2014) proposed the Northern Desert region as being closely related to Northern Australian Region, thereby being separate to the Eremaean.

Included Sub-regions. Central Desert *sub-regio nova,* Great Sandy Desert Interzone *sub-regio nova* and, Central Queensland *sub-regio nova.*

Sub-region CENTRAL DESERT *sub-regio nova*
(Fig. 3)

Diagnosis. The area east of the Great Sandy Desert bounded in the south by the Gibson Desert, the Macdonnell Ranges and the Simpson Desert. Extends into Queensland, bounded in the south by the Selwyn Range and the east by the Gregory Range, lying south of the Cape York, Arnhem Land and Kimberly sub-regions.

Type-locality. Mount Singleton, Northern Territory, 21°55'27.59"S 130°45'57.39"E.

Remarks. González-Orozco, Ebach *et al.* (2014) recovered a large central area within the Northern Desert region. While it covers much of Cracraft's original Northern Desert region, it extends further east and west into the Sandy Desert Interzone and Central Queensland sub-regions. The Central Desert sub-region is considered to the type for the Northern Desert Region.

Sub-region GREAT SANDY DESERT INTERZONE *sub-regio nova*
(Fig. 3)

Diagnosis. Extending east from Exmouth Gulf to the western edge of the Gibson Desert, near Lake Disappointment, moving north along the eastern edge of the Great Sandy Desert bordered in the north by the Fitzroy River.

Type-locality. Mount Edgar, Marble Bar, Western Australia, 21°14'22.51"S 120°10'00.18"E.

Remarks. The Great Sandy Desert Interzone is based on the analysis by González-Orozco, Ebach *et al.* (2014) and, includes the northern half of the Pilbara region, which is classified herein as part of the Northern and Eremaean regions.

Sub-region CENTRAL QUEENSLAND *sub-regio nova*
(Fig. 3)

Diagnosis. The area between Selywn and Gregory Ranges, extending onto the lower parts of the Great Dividing Range. Bounded in the west by the Simpson Desert and in the south by the dryer lowlands.

Type-locality. Kerr's Table Mountain, Kynuna, Queensland, 21°43'55.62"S 141°58'04.72"E.

Remarks. The Central Queensland sub-region is defined mostly by topography, and by the drier areas to the southwest. The higher parts of the Great Dividing Range, the Selwyn and Gregory Ranges and the Simpson Desert, including the drier and lower areas to the east, are clearly barriers to this sub-region.

Region SOUTHWEST AUSTRALIA Diels 1906
(Fig. 1)

(*Southwest Australia* Diels: 1906: 40)
(*Southwest* Crisp *et al.* 1995: 460)
(*Southwest Australian Floristic Region* Hopper & Gioia 2004: 633)
(*South-West WA Interzone Jarrah Forest* Ladiges *et al.* 2011: 32)
(*South-West WA Geraldton Sandplains* Ladiges *et al.* 2005: 1913)
(*South-West WA Interzone Wheatbelt* Ladiges *et al.* 2011: 32)
(*Goldfields* Ladiges *et al.* 2011: 32)
Southwest Australia Ebach *et al.* 2013: 324

Emended diagnosis. Triangular crescent shaped area between Shark Bay, Western Australia and Eucla in South Australia, extending as far inland as Lake Barlee, Western Australia.

Type-locality. Mount Magog, Stirling Range National Park, WA, Australia, 34°23'39.00"S 117°56'48.00"E.

Remarks. The Southwest region has retained similar boundaries since it was first described by Tate in 1889 (as Autochthonian). Several revisions by Diels (1906), Gardener (1944), Burbidge (1960) and Ladiges *et al.* (2011), have seen the region increase in size. While Hopper (1979) extensively studied the vegetation and rainfall zones of southwestern Australia, he did not propose or define an explicit area. Rather Hopper (1979) defers to Diels (1906) and to several maps of Beard (1975, 1976). Hopper and Gioia (2004) however, have a region very similar to Diels (1906). Our revision follows the analysis presented by González-Orozco, Ebach *et al.* (2014), which overlaps in part with that of Ladiges *et al.* (2011) South-West WA. Discussion about the composition and species interactions and vegetation types is discussed extensively in Hopper (1979), Beard (2001), Hopper and Gioia (2004) and Rix *et al.* (2014).

Sub-regions included. Southwestern *sub-regio nova*, Southwest Interzone Ladiges *et al.* 2005 and Hampton Ladiges *et al.* 2005.

Sub-region SOUTHWESTERN *sub-regio nova*
(Fig. 3)

D**iagnosis.** Triangular area in Western Australia between Shark Bay and Esperance, bounded in the southwest by the coastline.

Type-locality. Mount Magog, Stirling Range National Park, WA, Australia, 34°23'39.00"S 117°56'48.00"E.

Remarks. The Southwestern sub-region is proposed herein as the region that encompasses much of the high biodiversity found closer to the coast. The area is closer to that described by Tate (1889) as "restricted to the south-west corner of West Australia, and approximately coinciding with the rain-fall limit of twenty inches" (Tate 1889: 315), which is noted on his Rainfall Map. The area is also larger than that of Ladiges *et al.* (2011) (see Ebach *et al.* 2013: 324).

Sub-region SOUTHWEST INTERZONE Ladiges *et al.* 2005
(Fig. 3)

(*Interzone 1* Burbidge 1960: 79–80)
(*South West* Interzone Hopper 1979)
(*South-west Interzone* Ladiges *et al.* 2005: 1913)
(*Esperance* Ladiges *et al.* 2005: 1913)

Diagnosis. The area delineated by the Southwestern sub-region to the west and the Eremaean Region to the east.

Type-locality. Mount Geraldine, Mount Jackson WA, Australia, 29°58'0.00"S 119°24'0.00"E.

Remarks. The Southwest Interzone has been discussed by Nicholls (1933), Burbidge (1960) and Hopper (1979), the former two authors named it Hesperonotian and Interzone 1 respectively. Burbidge mapped Interzone 1 in her Fig. 1, and Hopper (1979) refined its boundaries in his Fig. 2, but also referred to the area as the "Transitional Rainfall zone". Nicholls based his area on "a less well-defined borderland, overlapping the Eremian [and Southwest Australia] and agreeing fairly closely with Prescott's Sclerophyll Woodland and Scrub" (Nicholls 1933: 94), whereas Burbidge described it as "a triangular area lying between the South-West Province and the Eremaea proper" (Burbidge 1960: 80). Given that these description are vague, we follow the area descriptions and name of Ladiges *et al.*, namely "Semi-arid area inland and adjacent to the South-west region, including open scrub and shrublands (on sand plains, sand over laterite or loamy soils) in the bioregions of Yalgoo, Avon Wheatbelt and Mallee" and that of the synonymised area

Esperance “Coastal region to the south-east [to the South-west interzone]” (Ladiges *et al.* 2005: 1913). Esperance and the Southwest Interzone are both herein considered to be the same area as they both correspond with the area recovered in the analysis of González-Orozco, Ebach *et al.* (2014).

Sub-region HAMPTON Ladiges *et al.* 2005
(Fig. 23)

Hampton Ladiges *et al.* 2005: 1913

Diagnosis. Coastal dry region south of the Nullabor including the Roe and Israelite Plains.

Type-locality. Wurrengoodyea Hills, Madura Western Australia, Australia, 32°12’0.00”S 126°22’0.00”E.

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