Morphological and genetic relationships of the Dirk Hartog Island fieldwrens

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Rufous Fieldwren, *Calamanthus campestris*, Dirk Hartog Island

Summary

The taxonomy of the fieldwrens (*Calamanthus* spp.) has been controversial for the last century. Multiple species and subspecies have been proposed. Some authors have recognised two species and up to seven subspecies in Western Australia. Two of these (*C. campestris hartogi* which is restricted to Dirk Hartog Island and *C. c. dorrie* which is restricted to Bernier and Dorre Islands) are currently listed as Vulnerable. We hypothesised that variation in Western Australia is clinal, and that all populations are part of the same species, *C. campestris*, without any subspecies being recognisable. Results of our morphological and genetic analyses are consistent with this hypothesis. We recommend that *C. campestris hartogi* and *C. c. dorrie* are both nominated for removal from threatened species lists, but that the Dirk Hartog Island population be considered a Management Unit (MU) for conservation management purposes.

Introduction

It is important that conservation management is underpinned by sound taxonomy and biosystematics, providing the basis for identification of evolutionary significant units and management units (e.g. Moritz 1999), hence enabling informed decisions to be made and to allow optimal allocation of resources for conservation of those units. In many groups, this is relatively straightforward, but in some, including the Australian bird family Acanthizidae (thornbills and allies), this has proved quite challenging. The acanthizids are an Australo-Papuan group of about 60 small insectivorous bird species, around which there has been much uncertainty concerning their evolution, relationships and taxonomic nomenclature (e.g. Marki *et al*. 2017, Norman *et al*. 2018). The fieldwrens, genus *Calamanthus*, well illustrate the complexities, both from an evolutionary perspective and from the practicalities of determining conservation status of the putative entities. The range of past taxonomic treatments of *Calamanthus* lead to different possible outcomes in relation to the identification of management units and their conservation status. This is particularly relevant in Western Australia, where the list of threatened taxa included two subspecies of *Calamanthus campestris* (*C. c. hartogi* from Dirk Hartog Island, and *C. c. dorrie* from Bernier and Dorre Islands) based on the taxonomic conclusions of Schodde and Mason (1999), in contrast to the long-held view that variation in Western Australia is clinal (e.g. Johnstone and Storr 2004). Both taxa are listed as Vulnerable (Minister for Environment 2018). This poses a conundrum for conservation managers.

Relationships within the broader group have long been challenging for taxonomists. For example, the close relationship between *Sericornis* (scrub-wrens), *Hylacola* (heath-wrens) and *Calamanthus* (Schodde and McKean 1976) has led to proposals to synonymise *Calamanthus* and *Hylacola* with *Sericornis* (the older name) (Schodde 1975). However, Keast (1978) argued that the fieldwrens were better retained in *Calamanthus*, and the heathwrens in *Hylacola*, a conclusion supported on molecular grounds by Christidis (1990). Some recent authors (e.g. Johnstone and Storr 2004; Christidis and Boles 2008) have accepted this position, while others (Schodde and Mason 1999; del Hoyo and Collar 2016; Johnstone and Darnell 2017; Gill and Donsker 2018) include *Hylacola* (heath-wrens) in *Calamanthus*.

Within *Calamanthus sensu stricto*, there has been taxonomic uncertainty for the last century (Table 1). Earlier authors recognised up to four species (Mathews 1922; Ashby 1924; Royal Australasian Ornithologists Union 1926), but Condon (1951) simply recognised a single species, highly variable in colouration. This position was accepted by Schodde (1975), who also lumped the fieldwrens into the genus *Sericornis*.

Much of the uncertainty has been fuelled by different workers looking at different subsets of the available specimens, and coming to different subjective conclusions, but in a ground-breaking paper based on examination of a broad range of specimens and careful measurements, Parker and Eckert (1983) proposed to split the complex into two species – *C. fuliginosus* (Striated Fieldwren) in south-eastern Australia, and *C. campestris* (Rufous Fieldwren) which occurs from the southern Pilbara to north-western Victoria. Most subsequent authors have followed this arrangement, including Mayr (1986), Johnstone and Storr (2004), Christidis and Boles (2008) and Johnstone and Darnell (2017).

Schodde and Mason (1999) hypothesised that *C. campestris* could be regarded as two species, *C. montanellus* in south-western Australia and *C. campestris* from the south-western Pilbara to Shark

Bay, central western Australia and South Australia to the mallee of north-western Victoria. Thus, they regarded *Calamanthus* as containing three species, in contrast to the view of others who interpreted variation in *Calamanthus campestris* as clinal. Condon (1951) postulated that there is "perfect gradation in size, plumage pattern and plumage coloration from east to west and north to south, with intermediates between the various forms occurring at several places" and Johnstone and Storr (2004) stated that, in Western Australia, "there is smooth, clinal intergradation between the southern olive and northern rufous forms ..... and calls also appear identical".

Geographic variation in the group obviously is complex and not fully understood, leading to somewhat different subspecific treatments by different authors (Table 1). For example, Condon (1969) recognised six subspecies in South Australia while Schodde and Mason (1999) recognise four in that area and 12 overall. Serventy (1937) discussed the several available names for birds in the Shark Bay area and Schodde and Mason (1999) recognised three taxa in and near Shark Bay. On the other hand, Johnstone and Storr (2004) and Johnstone and Darnell (2017), while acknowledging considerable variation in colour patterns in Western Australia, have noted the lack of breaks in geographic distribution claimed by Schodde and Mason (1999) (see maps in Johnstone and Storr (2004)), have consistently viewed the variation as clinal, and have only recognised a single taxon (*campestris*) as occurring in Western Australia.

This taxonomic complexity and confusion is a reflection of the relevance this group has for the study of evolution of the Australian avifauna but, as noted above, it also has significance for conservation management. Accordingly, we sought to determine whether there were significant morphological and genetic differences between island and mainland populations of *C. campestris* s.l., in order to (a) contribute to an understanding of speciation processes in this group, (b) clarify the status of the two subspecies that are listed as of conservation concern (*C. campestris hartogi* which is restricted to Dirk Hartog Island and *C. c. dorrie* which is restricted to Bernier and Dorre Islands), and (c) clarify the status of putative species and subspecies in the group. We hypothesised that there would be no significant differences between the island populations and the adjacent mainland, and that in mainland populations there is north-south and east-west clinal variation, in contrast to Schodde and Mason's (1999) hypothesis that two separate species can be recognised in Western Australia.

Materials and Methods

Specimens and morphology

We made standard measurements of wing length (flattened chord), tail length (tip of retrices to base of tail), tarsus length, total culmen length, culmen depth and culmen width on specimens in the Western Australian Museum, South Australian Museum and Museums Victoria (H.L. White Collection). The geographic distribution of these specimens is shown in Figure 1.

Table 1. Major historical taxonomic treatments of *Calamanthus s.s.*, using the nomenclature of Schodde and Mason (1999), who recognised three species: *C. montanellus* (0 sspp.), *C. campestris* (7 sspp.) and *C. fuliginosus* (4 sspp.).

Names from Schodde and Mason (1999)	*montanellus*	*campestris*	*rubiginosus*	*dorrie*	*hartogi*	*wayensis*	*isabellinus*	*winiam*	*fuliginosus* s.l.
Ashby (1924) (4 spp.)	*montanellus* (a species "nearer to *fuliginosus* than *campestris*")	*campestris* (E of Eyre Peninsula); *isabellinus* (Eyre Peninsula and Nullarbor Plain)	*isabellinus*	*isabellinus*	*isabellinus*	*isabellinus*	*isabellinus*	*campestris*	*fuliginosus* (no subspecies recognised due to high levels of variation)
Serventy (1937) (?3 spp.)	*montanellus montanellus*	*isabellinus*	*isabellinus*	*montanellus dorrie*	*montanellus dorrie*	*isabellinus*	*isabellinus*	Not considered	Not considered
Condon (1951) (1 sp.)	Not considered	*fuliginosus campestris*, *f. ethelae* and *f. suttoni*	Not considered	Not considered	Not considered	Not considered	*f. isabellinus*	*fuliginosus howei*, *f. parsonsi* and *f. winiam*	*fuliginosus* (3 sspp)
Schodde (1975) (1 sp.)	*fuliginosus* (sspp. not considered)	*fuliginosus* (sspp. not considered)	*fuliginosus* (sspp. not considered)	*fuliginosus* (sspp. not considered)	*fuliginosus* (sspp. not considered)	*fuliginosus* (sspp. not considered)	*fuliginosus* (sspp. not considered)	*fuliginosus* (sspp. not considered)	*fuliginosus* (sspp. not considered)
Parker and Eckert (1983) (2 spp.)	*campestris montanellus*	*campestris campestris* and *campestris ethelae*	*campestris campestris*	*campestris dorrie*	*campestris dorrie*	*campestris campestris*	*campestris campestris*	*campestris winiam*	*fuliginosus* (no sspp)

Schodde and Mason (1999) (3 spp.)	*montanellus*	*campestris campestris*	*campestris rubiginosus*	*campestris dorrie*	*campestris hartogi*	*campestris wayensis*	*campestris isabellinus*	*campestris winiam*	*fuliginosus* (4 sspp)
Johnstone and Storr (2004) (2 spp.)	*campestris*	*campestris*	*campestris*	*campestris*	*campestris*	*campestris*	Not considered	Not considered	Not considered
del Hoyo and Collar (2016) (3 spp.)	*montanellus*	*campestris campestris*	*campestris rubiginosus*	*campestris dorrie*	*campestris hartogi*	*campestris wayensis*	*campestris isabellinus*	*campestris winiam*	*fuliginosus* (4 sspp)
Norman *et al*. (2018) (3 spp.)	*montanellus*	*campestris* (sspp. not considered)	*campestris* (sspp. not considered)	*campestris* (sspp. not considered)	*campestris* (sspp. not considered)	*campestris* (sspp. not considered)	*campestris* (sspp. not considered)	*campestris* (sspp. not considered)	*fuliginosus* (sspp. not considered)

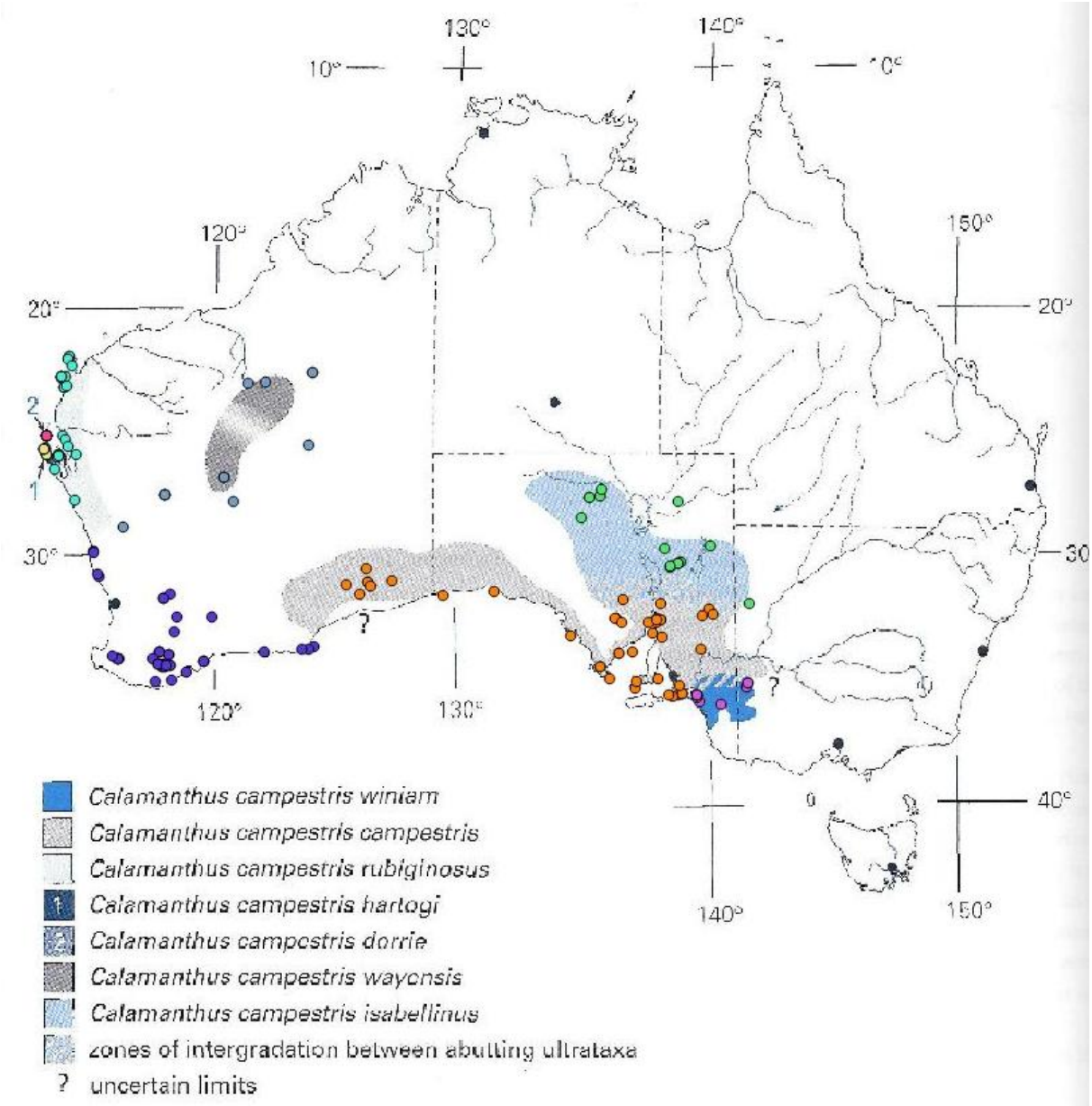

Figure 1. Geographic distribution of the museum specimens of *Calamanthus campestris* examined for the morphological aspects of this study, superimposed on the map provided by Schodde and Mason (1999). Details of the specimens are listed in Appendix 1. Using the nomenclature of Schodde and Mason (1999) (see Table 1), and going from west to east, *hartogi* = pale yellow, *dorrie* = pink, *rubiginosus* = aqua, *wayensis* = blue-grey, *montanellus* = deep blue, *campestris* = ochre, *isabellinus* = green, *winiam* = pink/purple.

Morphometric data were available for 180 individuals of *C. campestris* (122 males and 58 females) once juveniles and specimens with missing data were removed. Univariate comparisons were done in Microsoft Excel. Multivariate analyses were carried out in the program Primer v6 (Clarke and Gorley 2006) to reveal patterns of morphological similarity in the data matrix. All data were standardised, and the Euclidean resemblance measure was used to compare the specimens according to their morphometric similarities, by means of the CLUSTER procedure (hierarchical cluster analysis) combined with SIMPROF (similarity profiles) to test for significant evidence of

structure among the samples. We used ordination by multidimensional scaling (MDS) to visualise similarity of specimens in two-dimensional space.

Principal Component Analysis (PCA) was used to characterise patterns of environmental variables at the sites from which *Calamanthus* specimens came. Values were obtained from the spatial portal of the Atlas of Living Australia (ALA) website at http://www.ala.org.au. Data were obtained for Evaporation - annual mean, Precipitation - annual (Bio12), Temperature - annual mean (Bio01), Euclidean Distance to Coast (metres) and Fractional Cover - Persistent Vegetation (2012-03-05). Missing data were estimated using the 'Missing' tool in Primer, values were normalised, and then the PCA routine was run.

We set out to quantify colour and patterns by photographing the dorsal and ventral surfaces of *Calamanthus* skins in the Western Australian Museum. Examination of such images in computer graphics software allows the measurement of three colour values (RGB or HSL) for each area of interest. This process is still under development and testing, so will not be reported further here.

Genetic analysis

Preserved tissues collected by DBCA staff were deposited in the Western Australian Museum. These tissues were extracted in the WA Museum's Molecular Systematics Unit, along with other tissues from the Australian National Wildlife Collection, South Australian Museum and Museum Victoria. DNA was extracted from a total of 45 *Calamanthus* and 41 *Hylacola* preserved tissues.

Genomic DNA was extracted from ultra-frozen museum tissue of *Calamanthus* and *Hylacola* specimens (Western Australian Museum, Australian National Wildlife Collection, South Australian Museum, and Museum Victoria; see Appendix 2 for specimen details) using QIAGEN DNeasy Blood & Tissue Kit (QIAGEN Group).

The ND2 locus (1032 base pairs) was amplified from the 45 Calamanthus and 41 Hylacola samples using PCR and PCR amplicons were sequenced by AGRF using Sanger sequencing. DNA sequences were edited and aligned in Geneious version R10.2.3 (Kearse et al., 2012). *Smicrornis brevirostris* and *Pyrrholaemus brunneus* were chosen as outgroups based on a previously published phylogeny of ND2 in scrubwrens (Norman et al. 2018). Rapid Maximum likelihood methods (RaxML; Stamatakis, 2014) were used to generate a phylogeny using the General Time Reversible model, and a consensus phylogeny was produced based on 1000 bootstrap replicates.

Next generation sequencing library preparation and sequencing was performed by Australian Genome Research Facility (AGRF). A total of 44 DNA extractions were quantified and provided to AGRF, including 19 *Calamanthus fuliginosus*, 23 *C. campestris* and 2 *Hylacola pyrrhopygia* (used as outgroup).

AGRF used double digest Restriction Associated DNA (ddRAD) based library preparation protocol DNA was digested with PstI and MseI, as determined to perform best in trials. Barcoded adapters compatible with these restriction site overhangs were ligated on to the digested DNA, size selection was performed on pooled digested-ligated fragment using Blue Pippin (Sage Science) and the library was amplified using PCR indexed primers. The library was sequenced by AGRF on an Illumina HiSeq.

The Stacks pipeline (Stacks version 1.41; Catchen *et al*., 2013) was used to generate stacks of reads present in all samples, check the quality of reads and trim to the shortest read minus 2 base pairs.

Variant sites were then extracted from these reads. The average number of tags (read stacks) in the catalogue is 182,171 and the average Tag depth is 10.1 reads.

A cluster analysis was performed on the matrix of genome-wide identity by state pairwise distances, with groups determined by a permutation score. This analysis was performed using SNPRelate, an R/Bioconductor Package.

Results

Morphometric analyses

On average, males are larger than females in both western (Figures 2, 3) and eastern Australia (Figures 4, 5), and so have been treated separately in the following analyses.

(a) Is there a cline in size in Western Australia?

Both male (Fig. 2) and female (Fig. 3) *C. campestris* in Western Australia show an increase in wing and tail length with increase in latitude. This variation appears to be clinal, and no obvious disjunctions in size are apparent. Although birds from Dirk Hartog have relatively short wings and long tails, the differences are not statistically significant. Neither culmen nor tarsal lengths vary geographically for either male or female *C. campestris* in Western Australia.

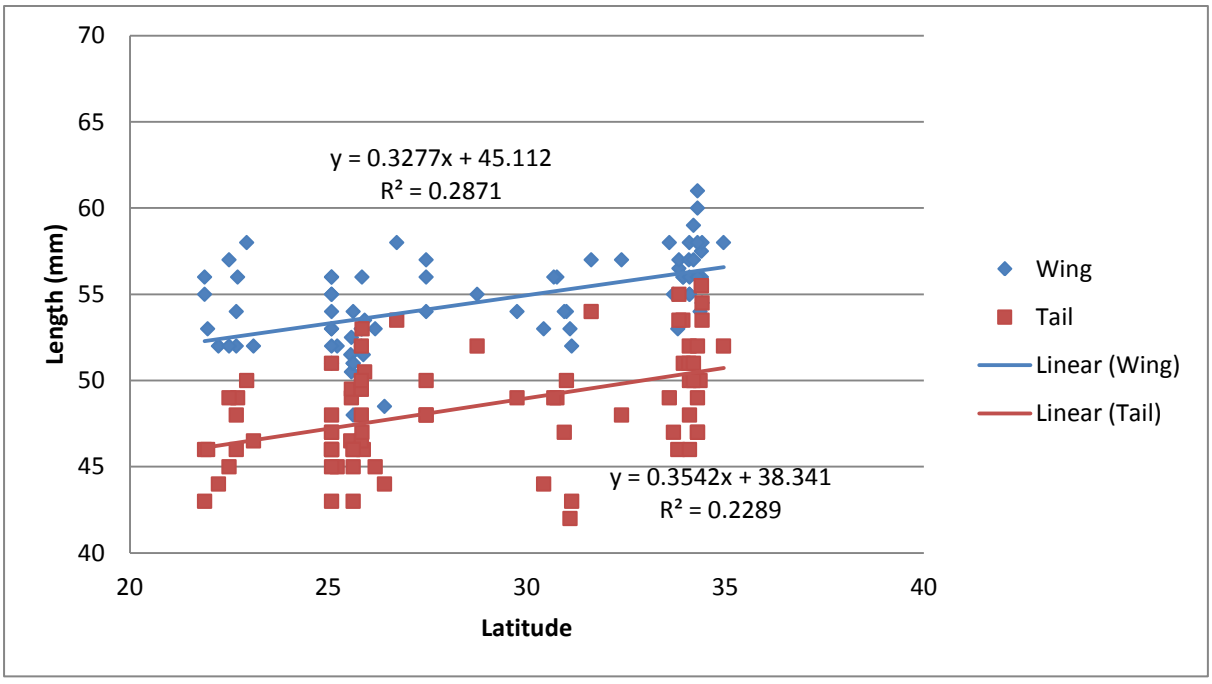

Figure 2. Latitudinal variation in wing and tail length in male *Calamanthus campestris* in Western Australia.

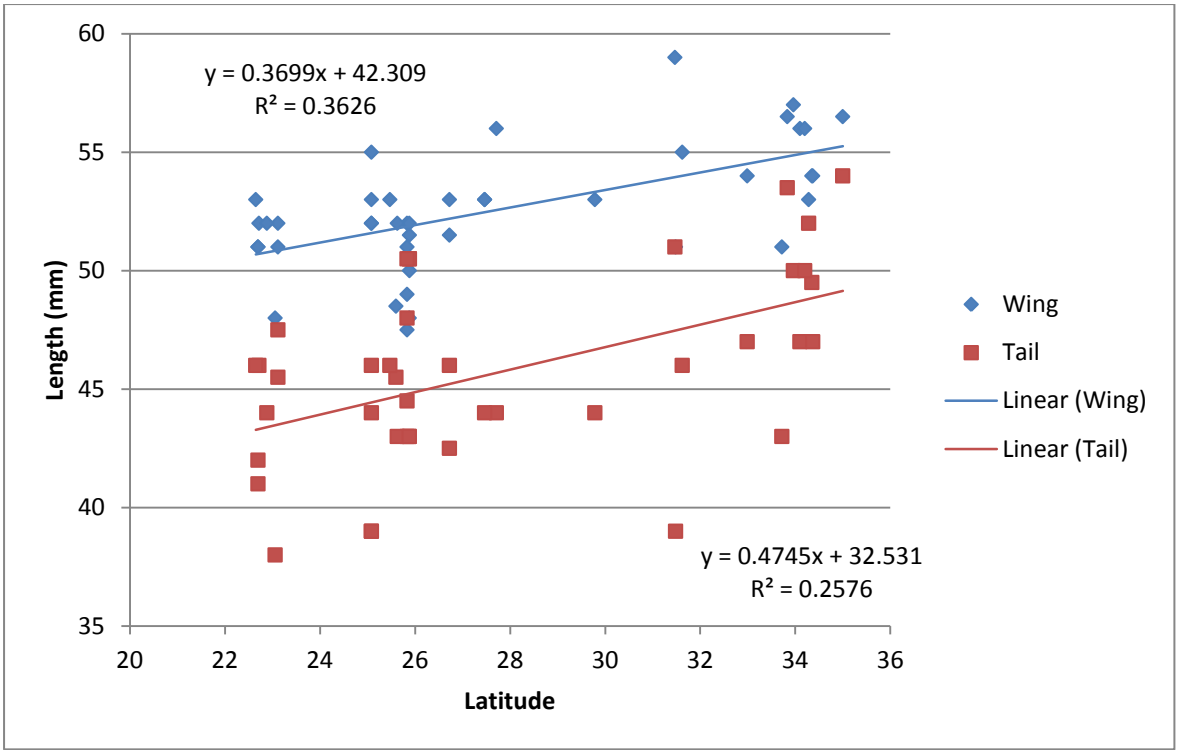

Figure 3. Latitudinal variation in wing and tail length in female *Calamanthus campestris* in Western Australia.

(b) Is there a cline in size in eastern C. campestris s.l.?

We could not detect a relationship between latitude and wing length or tail length in male specimens of eastern *C. campestris* (Figure 4). We did not have enough specimens of females to be sure of what relationships may occur, because there were too few specimens from the northern part of the geographic range (Figure 5). It is likely, however, that they would show a similar pattern to males.

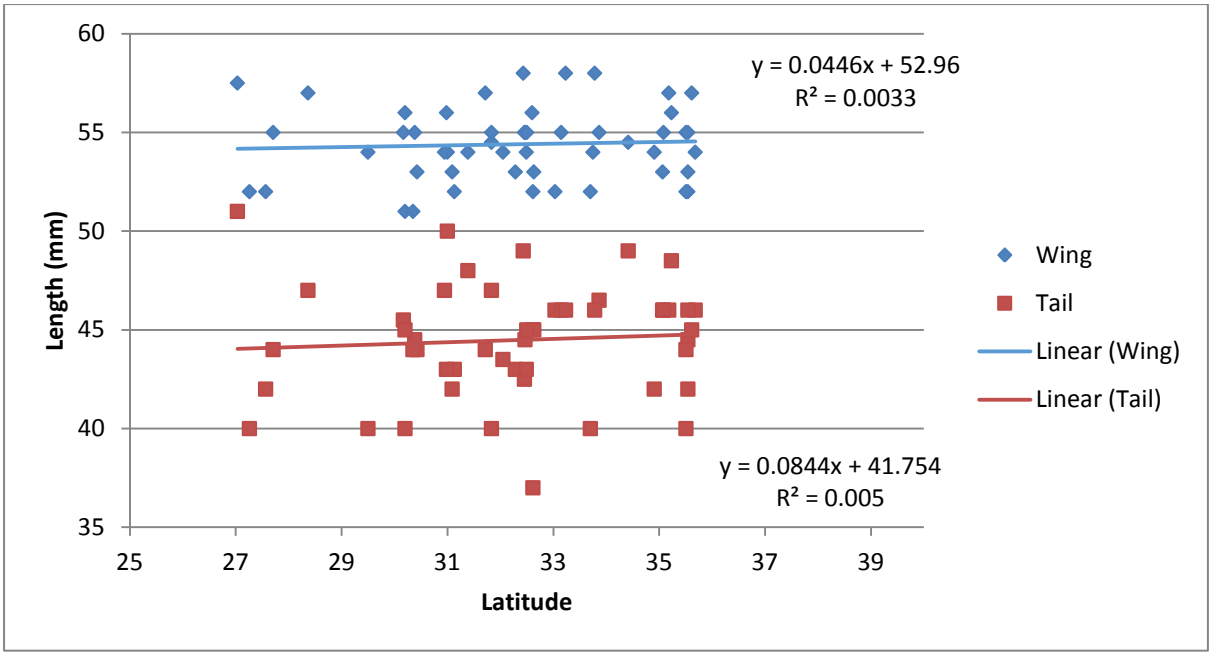

Figure 4. Latitudinal variation in wing and tail length in male *Calamanthus campestris* in eastern Australia, including *C. c. campestris* from the Western Australian Nullarbor.

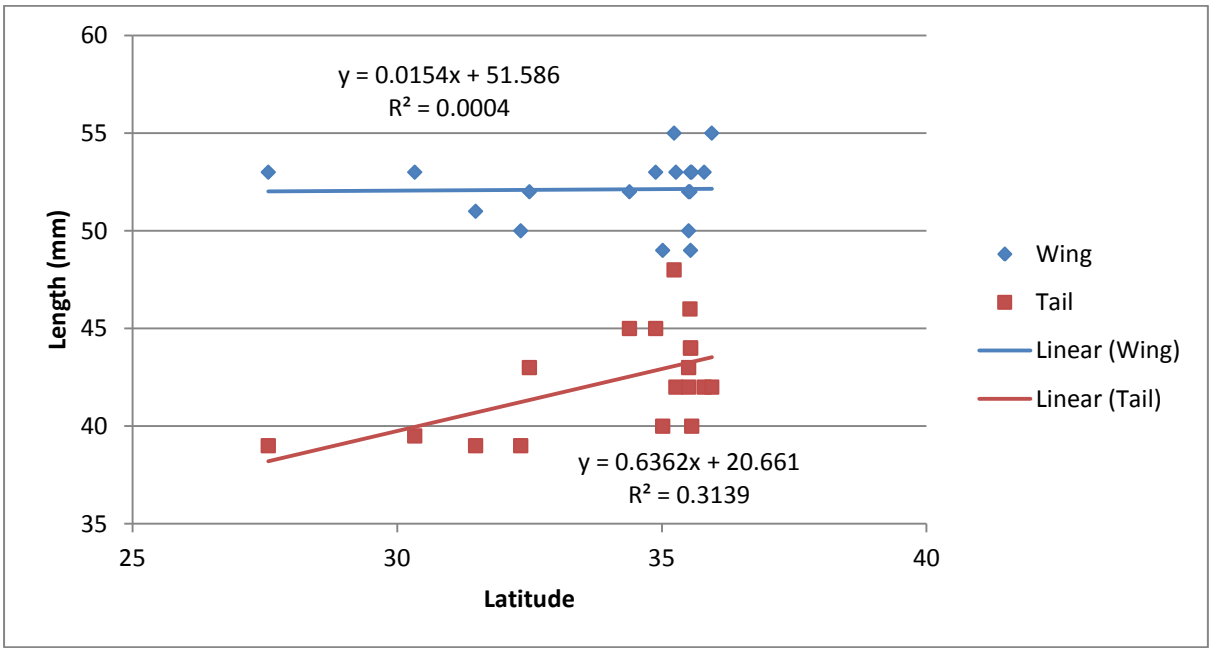

Figure 5. Latitudinal variation in wing and tail length in female *Calamanthus campestris* in eastern Australia, including *C. c. campestris* from the Western Australian Nullarbor.

(c) Is there morphometric support for any of the described sub-specific taxa?

There were 116 male specimens for which we had data on wing length, tail length, tarsus length, culmen length, bill width, and bill depth. A classification analysis of these 116 specimens did not reveal any grouping that clearly corresponded with any of the previously described sub-specific taxa (Figure 6). Four groups of specimens showed significant differences, but none of these groups corresponded with previously identified taxa, and there was no geographic pattern evident in the groupings. In particular, specimens from Dirk Hartog Island (*C.c. hartogi*) (green in Figure 6) and Bernier and Dorre Islands (*C.c. dorrie*) (ochre in Figure 6) were distributed within groups that contained a broad array of mainland specimens, indicating that these island populations are not distinguishable on the basis of the morphometric measurements we used.

Similarly, an ordination analysis (nMDS) of all male specimens (Figure 7) did not show any clear groups either; nor did it show any clear separation between eastern and western populations or any clear clinal variation. Not surprisingly, a similar analysis using only western males did not show groupings corresponding to previously described sub-specific taxa, or any clear clinal trends (Figure 8).

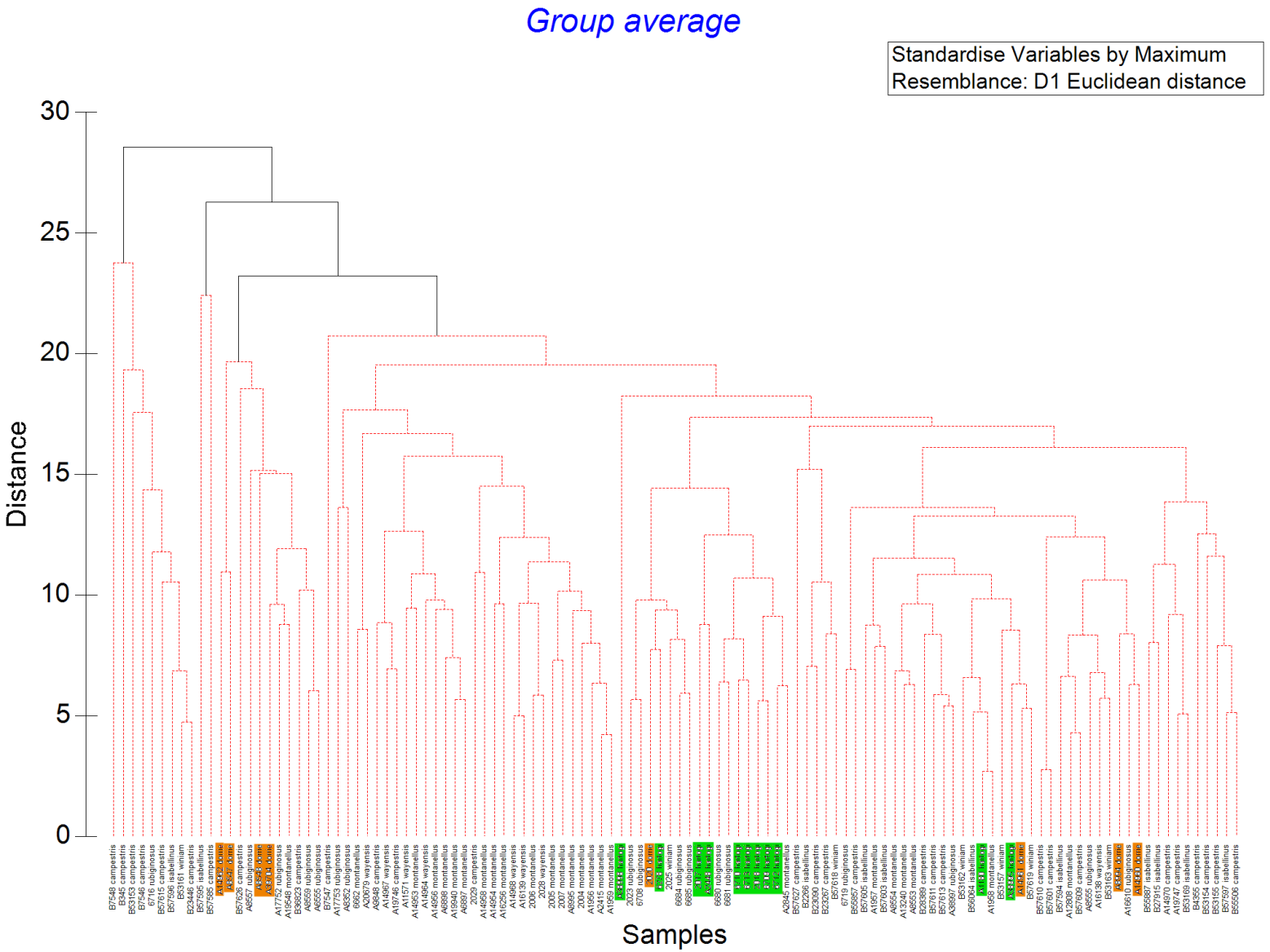

Figure 6. Classification of 116 male specimens of *Calamanthus campestris* s.l. on the basis of similarity in morphological measurements. Specimens from Dorre Island are highlighted in ochre, and specimens from Dirk Hartog are highlighted in green. The solid black lines indicate the four groups identified as different in the SIMPROF routine in Primer.

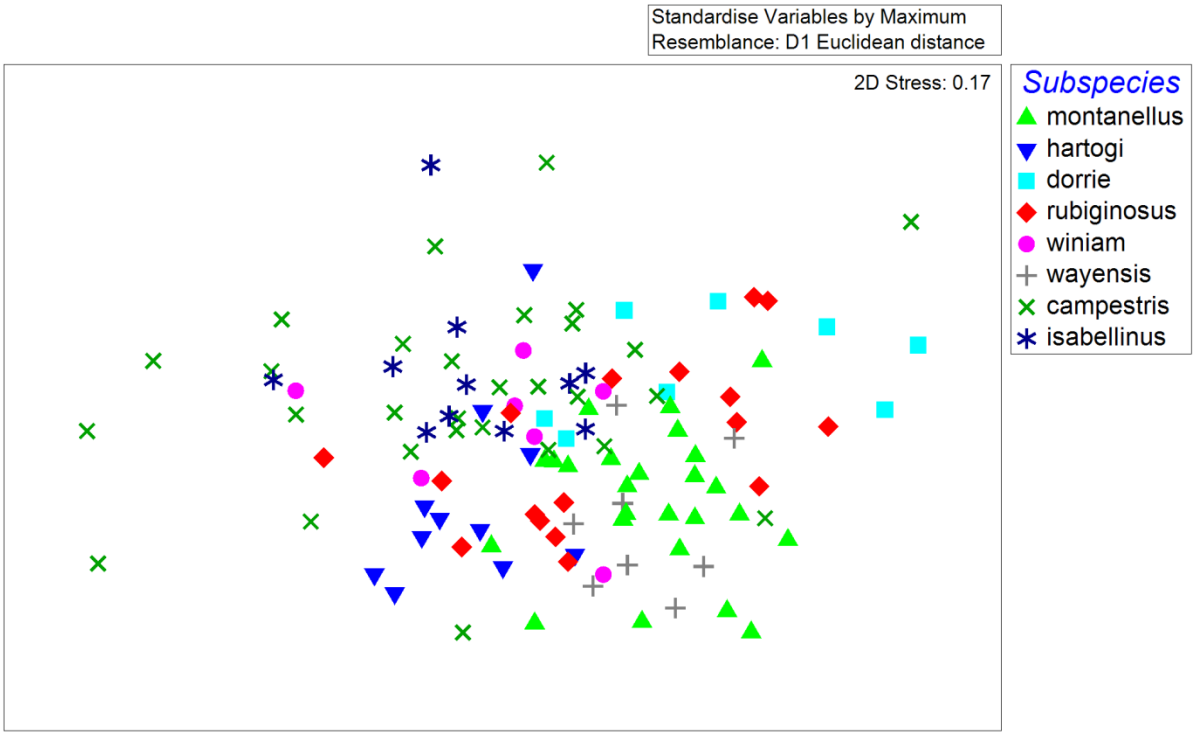

Figure 7. Ordination analysis (nMDS) of 116 male specimens of *Calamanthus campestris* s.l. from southern Australia.

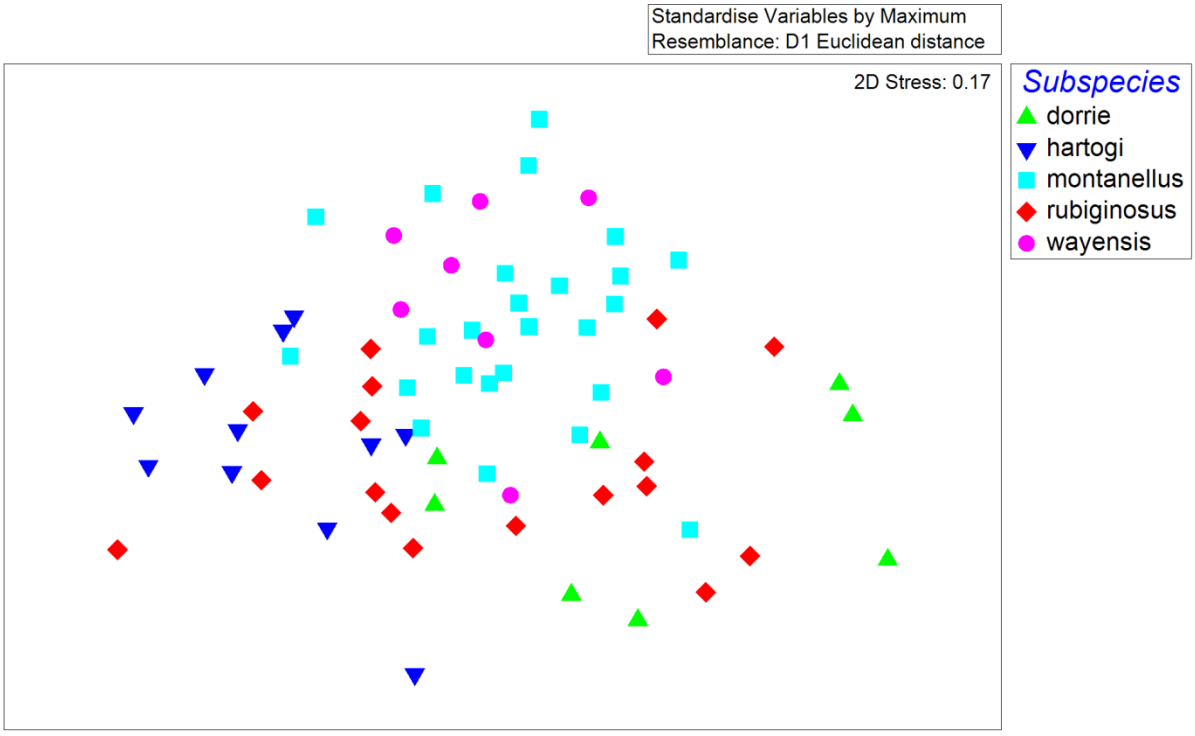

Figure 8. Ordination analysis (nMDS) of 69 male specimens of *Calamanthus campestris* s.l. from Western Australia.

Environmental parameters at collection sites

Principal component 1 (PC1), which accounts for 68.6% of the variation (Figure 9), was positively associated with annual precipitation and vegetation cover, and negatively with annual mean evaporation and temperature, with *montanellus* sites having high values on this axis, and *wayensis* sites having low values, with the other subspecies having intermediate values. PC2 (explaining 19.8% of the variation) was associated with distance to the coast.

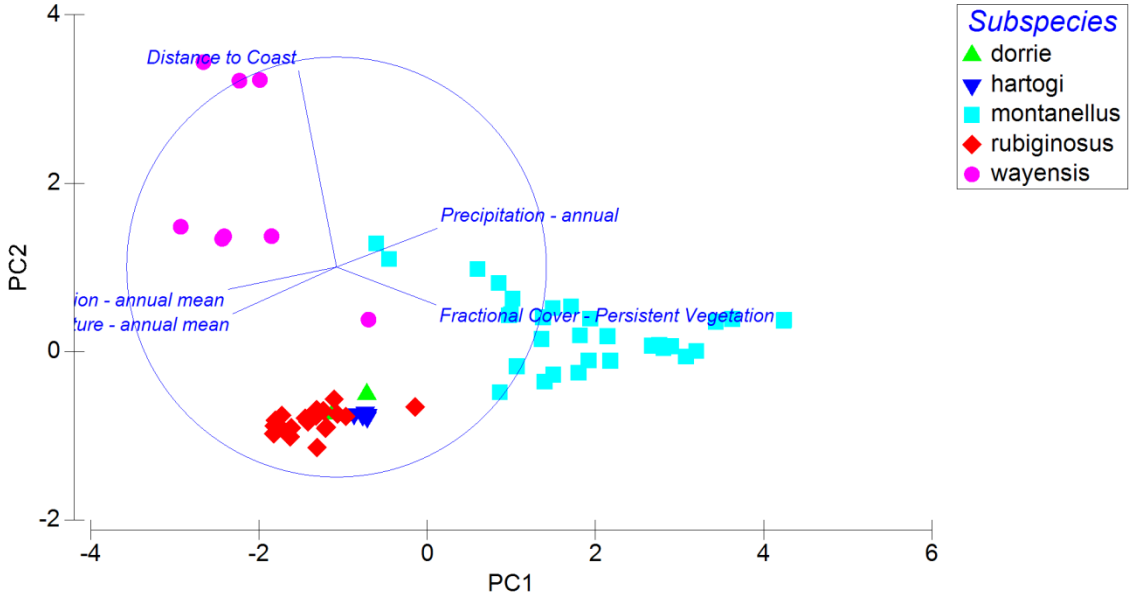

Figure 9. Principal components analysis (PCA) of the collection sites for the Western Australian *Calamanthus* specimens measured. Symbols indicate the subspecies (from Schodde and Mason 1999) from each site.

Mitochondrial phylogeny

The phylogeny estimated from 1032 bp *ND2* mitochondrial gene using RaxML, 1000 bp replicates reveal the genera *Hylacola* and *Calamanthus* to be well supported (bootstraps of 100) reciprocally monophyletic lineages (see Figure 10). There is 14.4% pairwise divergence between *Hylacola* and *Calamanthus*. Here we are interested in the evolution within *Calamanthus*. *Calamanthus* is divided into two major lineages with high bootstrap support (bs =100), *Calamanthus fuliginosus* and *C. campestris* are 7.2% divergent. There is no apparent phylogenetic structure within *C. fuliginosus* as it consists of a large polytomy. Within *C. campestris* there are two major lineages (bs=100), which are 3.2% divergent. The geographic division between these two lineages is broadly coincident with the Eyrean Barrier, a well-documented barrier in Australian birds (see Dolman and Joseph, 2012, 2015). The western lineage consists of birds from the Nullarbor region and Western Australia, and the eastern lineage consists of birds from the Lake Eyre Basin, Flinders Ranges, southern South Australia and far western Victoria (see Figure 11).

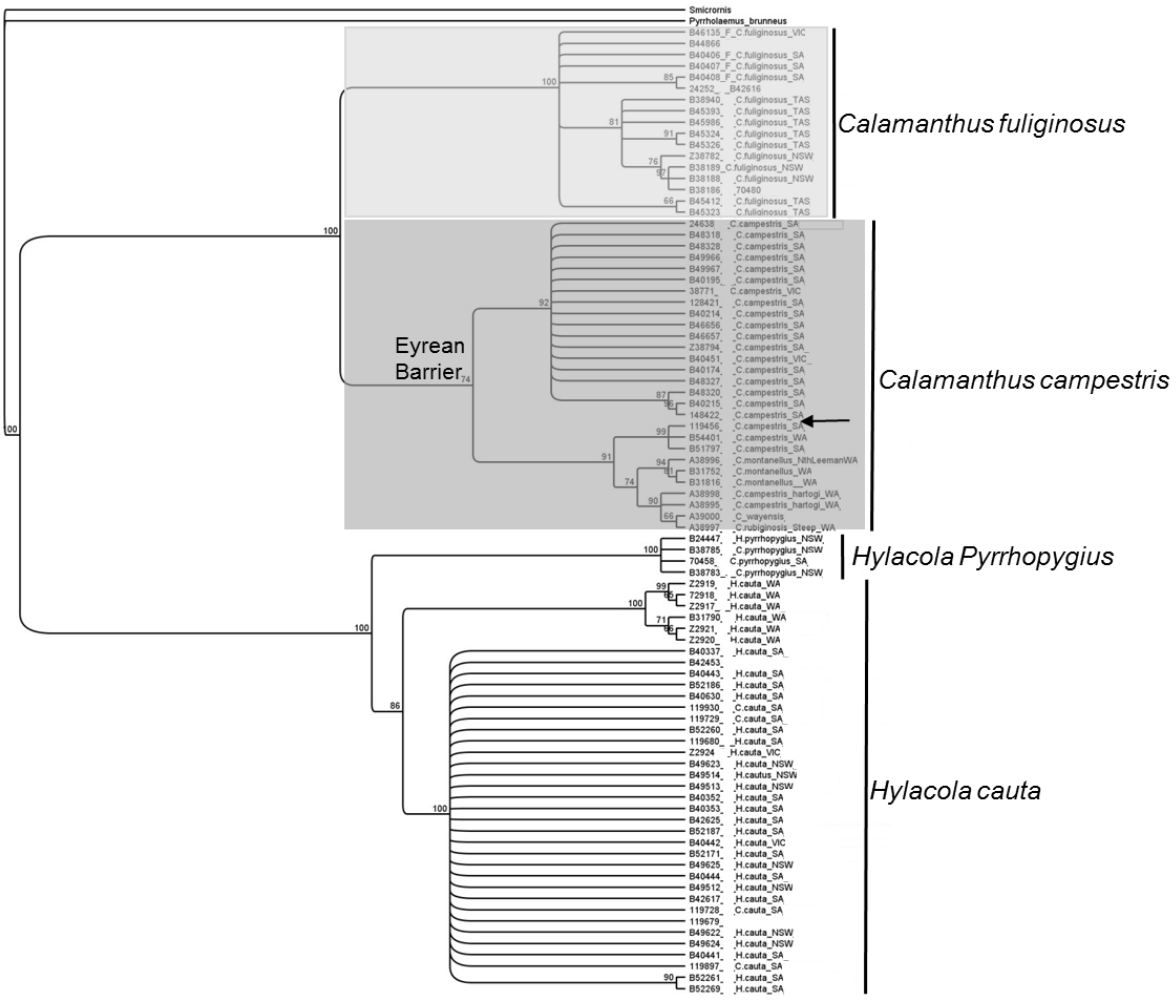

Figure 10. Consensus mitochondrial phylogeny (ND2 – 1032 bp) based on 1000 bootstrap replicates of RaxML

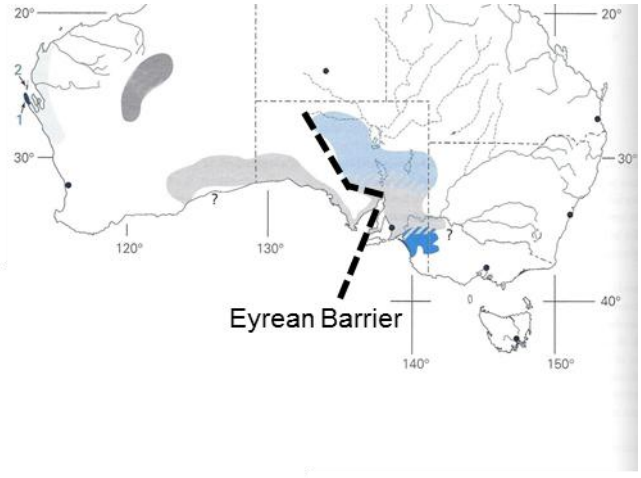

Figure 11. Map showing the location of the genetic break between western and eastern lineages of *Calamanthus campestris,* which is broadly coincident with the Eyrean Barrier, a well-documented geographic barrier in a number of Australian passerines. The eastern lineage consists of a large polytomy, and while there is more phylogenetic structure apparent in the western lineage, it is not consistent with existing recognised subspecies.

Genome-wide cluster analysis

The cluster analysis of genome-wide Identity by state pairwise distances is based on a total of 1,183,844 biallelic Single Nucleotide Polymorphisms (SNPs). The significant difference between the mitochondrial phylogeny and the genome wide cluster analysis is that, whereas in the mtDNA, *C. campestris* consists of two lineages broadly separated by the Eyrean Barrier, the genome wide data comprises three lineages: a Dirk Hartog Island lineage sits outside of the eastern and western lineages (Figure 12).

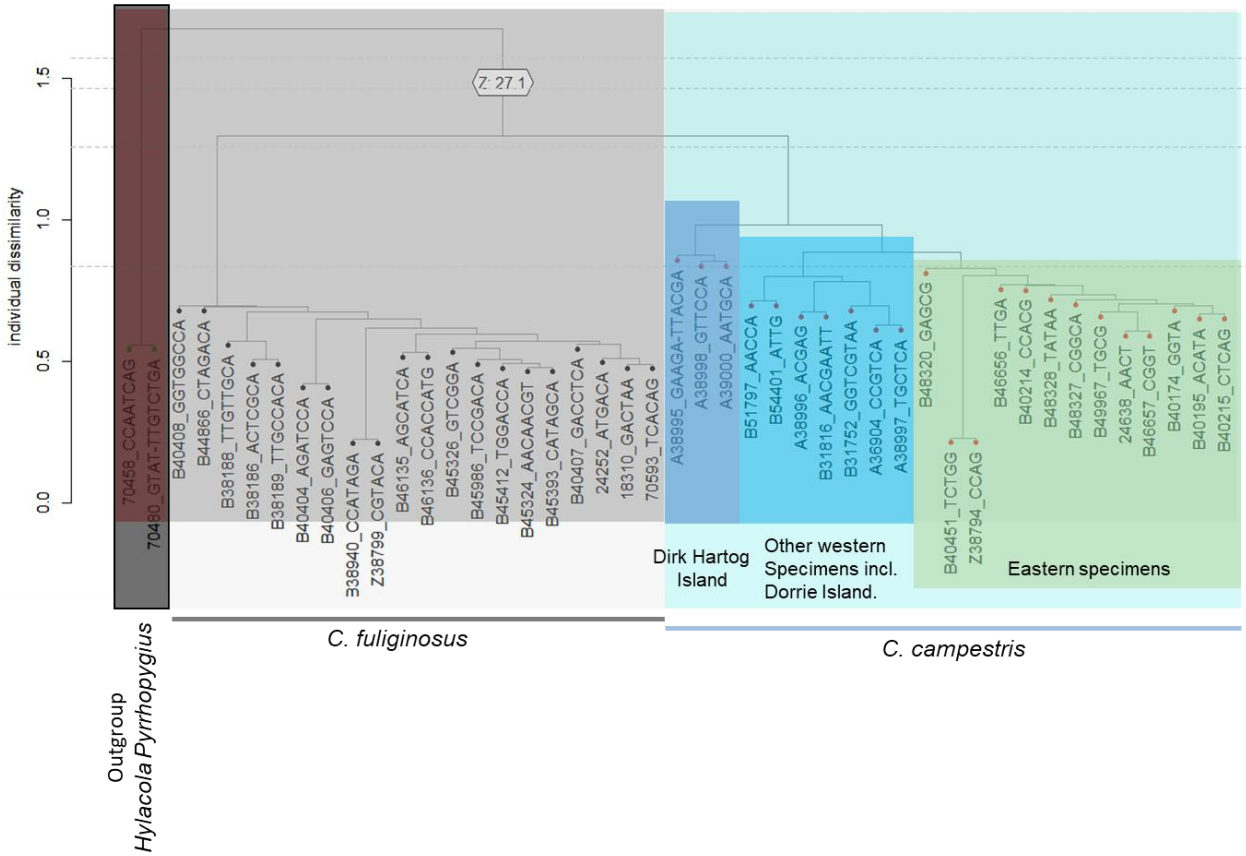

Figure 12. Genome-wide cluster analysis based on 1,183,844 biallelic SNPs from *Calamanthus fuliginosus* and *C. campestris* from southern Australia.

Discussion

Morphological analyses

Uni-variate analyses of morphometric parameters in *C. campestris* s.l. revealed a clinal relationship with latitude in Western Australia, and this is presumably an example of 'Allen's Rule' which states that in endothermic animals the relative sizes of appendages such as limbs are smaller in colder environments (e.g. VanderWerf 2012). However, at least for males, we did not detect any relationship with latitude in eastern Australia. These analyses are consistent with the hypothesis

(e.g. Johnstone and Storr 2004) that variation is clinal, noticeably in Western Australia but only weakly in eastern Australia.

Multivariate analyses of morphological data did not provide any evidence in support of the taxonomic groupings described by Schodde and Mason (1999) and others. In particular, it does not support elevation of birds from the south-west as a separate species (*C. montanellus*) and it does not support recognition of the populations from Dirk Hartog, Bernier and Dorre Islands as separate subspecies. Overall, the morphological data indicate that *Calamanthus campestris* s.l. only consists of a single taxon, and that further subdivision is not warranted.

Genetic analyses

The analyses reported here provide strong support for the contention of Parker and Eckert (1983) that there are two clearly identifiable species of fieldwren: Striated Fieldwren *C. fuliginosus* of south-eastern Australia and *C. campestris* Rufous Fieldwren which occurs from western Victoria to the west coast of Western Australia. There is no support for the suggestion by Schodde and Mason (1999) that there are two species in south-western Australia; in contrast, samples attributed to *C. montanellus* appear in the same lineage as samples from *C. campestris*. However, we did identify a clear genetic distinction between eastern and western populations, with a significant break at the Eyrean Barrier (Figure 10). This parallels the situation in some other east-west pairs of taxa, including various parrots and passerines (Murphy *et al*. 2011; Dolman and Joseph 2015; Burbidge *et al*. 2017), where the Eyrean Barrier appears to have played a major role in their phylogenetic structure.

With respect to birds on Dirk Hartog Island, there are not multiple lines of evidence to recognise *C. c. hartogi* taxonomically, despite the demonstrated genetic differences revealed in our SNP analysis. Recognition would require splitting *C. campestris* into three species (Dirk Hartog birds, all other western birds, and eastern birds).

Similarly, results of our genetic analyses do not provide any support for the contention that birds from Bernier and Dorre Islands should be recognised at subspecies level. It is not clear why the Dirk Hartog Island birds are genetically differentiated from both the Dorre and mainland birds, but the Dorre Island birds not genetically different from mainland birds. This situation is surprising, given that Bernier and Dorre Islands are much further offshore (about 40 km from the mainland and about 27 km from Dirk Hartog Island, whereas Dirk Hartog is less than 2 km from the mainland at the nearest point), and Bernier and Dorre have been separated from the mainland for longer (about 8000 years compared with about 6000 for Dirk Hartog) (Abbott 1978). Fieldwrens appear capable of flying from Dirk Hartog to the mainland even today (REJ pers. obs.) but perhaps they do not do this often enough for the populations to be panmictic. On the other hand, the smaller Bernier and Dorre population may have been more affected by gene flow in the past, or the population may have been extirpated in the past and recolonised by mainland birds, or fieldwrens may have been absent from these islands at the time of separation from the mainland, and not colonised until more recently.

Other factors

(a) Plumage colour

Although we have not yet been able to quantify colour variation in fieldwrens, it is known (Johnstone and Storr 2004) (Figure 13) that birds in inland Western Australia are paler and more

rufous than those from the extreme south-west. Quantification of the geographic patterns in pigmentation will confirm whether the variation is stepped (in association with putative taxon boundaries) or whether, as it appears from inspection of a long series of museum specimens (REJ pers. obs.), it is a smooth gradation similar to the situation we have documented for morphological characters.

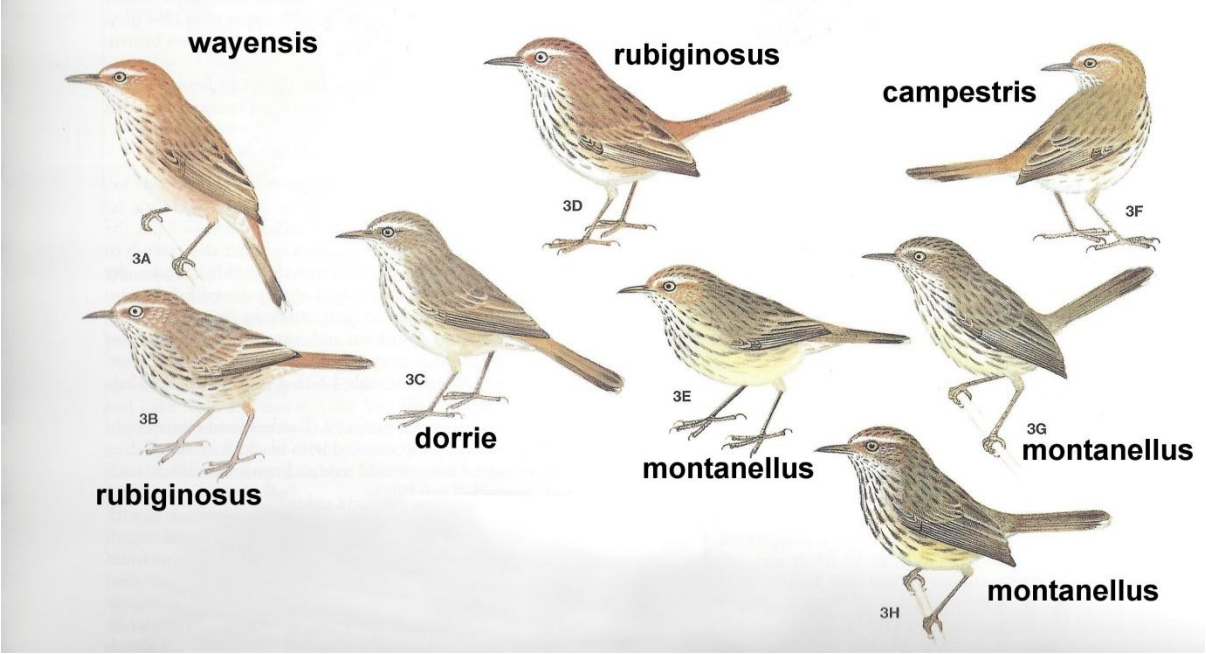

Figure 13. Illustration from Johnstone and Storr (2004), superimposed with names from Schodde and Mason (1999). Inland birds (top left) are paler and more rufous than birds from the south-west (bottom right). Intermediate shades and patterns also occur.

(b) Variation in Songs

It has been postulated (Gregory 2018) that the voice of *montanellus* is different from that of *campestris*, and this has been put forward as evidence supporting the hypothesis that these populations represent different species. However, our (unpublished) field observations indicate that there is much individual variation in *Calamanthus* calls, and individuals will respond to broadcast of calls from populations that are widely separated geographically. For example, on one occasion, we observed birds on Dirk Hartog island to respond very strongly to calls of *Hylacola cauta* (*Calamanthus cautus*). The current knowledge on calls, therefore, does not support the splitting of *C. montanellus* from *C. campestris*.

Implications for conservation management

On the basis of our morphological and genetic data, there are no valid subspecific taxa within *Calamanthus campestris* s.l., and the yet to be quantified patterns in pigmentation and voice appear consistent with this conclusion. In particular, the island populations *C. campestris dorrie* and *C. c. hartogi* are not valid taxa, and should be removed from threatened species lists. Nevertheless, the genetic differences between birds on Dirk Hartog Island and all other populations suggests that, although the Dirk Hartog Island birds have not been demonstrated to be an Evolutionary Significant

Unit (ESU), they should be treated as a Management Unit (MU) (*sensu* Moritz 1994, Funk *et al*. 2012) for conservation management purposes.

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Appendix 1. Location data for *Calamanthus campestris* specimens used in morphometric analyses.

Institution	Collection	Reg Number	State	Precise Location	Latitude	Longitude
MV	HLW	2002	WA	Lake Balicup Stirling Ranges	-34.28333333	117.7833
MV	HLW	2003	WA	Stirling Ranges	-34.35	117.7333
MV	HLW	2004	WA	Stirling Ranges	-34.41666667	117.7333
MV	HLW	2005	WA	Stirling Ranges	-34.4	117.8333
MV	HLW	2006	WA	Stirling Ranges	-34.41666667	117.7333
MV	HLW	2007	WA	Stirling Ranges	-34.4	117.8333
MV	HLW	2009	WA	Wilsons Inlet	-35	117.4833
MV	HLW	2017	WA	Dirk Hartog Is	-25.56666667	113
MV	HLW	2018	WA	Dirk Hartog Is	-25.58333333	113
MV	HLW	2019	WA	Dirk Hartog Is	-25.6	113.0167
MV	HLW	2020	WA	Peron Shark Bay	-25.88333333	113.55
MV	HLW	2021	WA	Peron Shark Bay	-25.88333333	113.55
MV	HLW	2022	WA	Peron Shark Bay	-25.88333333	113.55
MV	HLW	2023	WA	Point Cloates	-22.68333333	113.7
MV	HLW	2025	Vic	Kow Plains	-35.23333333	141.3833
MV	HLW	2026	SA	Wantapella Swamp	-27.03333333	133.4667
MV	HLW	2027	WA	Lake Way East Murchison	-26.725	120.25
MV	HLW	2028	WA	Lake Way East Murchison	-26.725	120.25
MV	HLW	2029	WA	Haig Nullarbor Plain	-31	126.0833
MV	HLW	2030	WA	Haig Nullarbor Plain	-31	126.0833
MV	HLW	6278	WA	Dirk Hartog Is	-25.58333333	113
MV	HLW	6660	WA	Broomehill	-33.83333333	117.6333
MV	HLW	6661	WA	Broomehill	-33.83333333	117.6333
MV	HLW	6662	WA	Gnowangerup	-33.93333333	118.0167
MV	HLW	6680	WA	Peron Peninsula Shark Bay	-25.83333333	113.55

MV	HLW	6681	WA	Peron Peninsula Shark Bay	-25.83333333	113.55
MV	HLW	6682	WA	Peron Peninsula Shark Bay	-25.83333333	113.55
MV	HLW	6683	WA	Maud's Landing	-23.11666667	113.7667
MV	HLW	6684	WA	Maud's Landing	-23.11666667	113.7667
MV	HLW	6685	WA	Point Cloates	-22.68333333	113.7
MV	HLW	6708	WA	[Denham] Peron Peninsula	-25.91666667	113.5333
MV	HLW	6709	WA	Dirk Hartog Is	-25.83333333	113.05
MV	HLW	6710	WA	Dirk Hartog Is	-25.83333333	113.05
MV	HLW	6711	WA	Dirk Hartog Is	-25.83333333	113.05
MV	HLW	6712	WA	Dirk Hartog Is	-25.83333333	113.05
MV	HLW	6713	WA	Dirk Hartog Is	-25.83333333	113.05
MV	HLW	6714	WA	Dirk Hartog Is	-25.83333333	113.05
MV	HLW	6715	WA	Dirk Hartog Is	-25.83333333	113.05
MV	HLW	6716	WA	Edel Shark Bay	-26.41666667	113.4167
MV	HLW	6717	WA	Maud's Landing	-23.11666667	113.7667
MV	HLW	6718	WA	Point Cloates	-22.71666667	113.6667
MV	HLW	6719	WA	Point Cloates	-22.71666667	113.6667
AMNH		587869	WA	Broomehill	-33.83333333	117.6333
AMNH		587919	WA	Woolundra	-31.62361111	117.7875
AMNH		587927	SA	Marble Range Eyre Peninsula	-34.41666667	135.4833
AMNH		587933	Vic	Kow Plains	-35.23333333	141.3833
AMNH		587938	NSW	10 ml N of Broken Hill - Wyurra	-31.83333333	141.5
AMNH		587957	WA	Dorrie Is	-25.08333333	113.1083
AMNH		587961	WA	Lake Way	-26.725	120.25
WAM		A10535	WA	Kalbarri NP sandplain	-27.68888889	114.2069
WAM		A11543	WA	North Tarin Rock (10 miles N of Tarin Rock)	-32.99027778	118.2361
WAM		A11571	WA	2 miles E of old Talawana HS	-22.94444444	121.2167
WAM		A1180	WA	Dirk Hartog Island	-25.62777778	112.9931

WAM		A1181	WA	Dirk Hartog Island	-25.62777778	112.9931
WAM		A12715	WA	8 miles W of Mt Nossiter	-25.44027778	123.6708
WAM		A12808	WA	Lake Warden	-33.80555556	121.8778
WAM		A12809	WA	3 Mile Lagoon near Denham	-25.88055556	113.5472
WAM		A13240	WA	Opposite Flat Rock between Green Islets and Wedge Island	-30.75972222	115.1847
WAM		A14426	WA	4 miles N of Coral Bay t/o on Exmouth Gulf road	-23.05833333	113.8889
WAM		A14953	WA	Cranbrook	-34.30138889	117.5681
WAM		A14954	WA	Cranbrook	-34.30138889	117.5681
WAM		A14955	WA	Cranbrook	-34.30138889	117.5681
WAM		A14956	WA	Cranbrook	-34.30138889	117.5681
WAM		A14957	WA	Yetermirrup	-34.35277778	117.9181
WAM		A14958	WA	Gracefield [W of Tambellup]	-34.09527778	117.3428
WAM		A14959	WA	Mount Sir Samuel	-27.7125	120.6472
WAM		A14960	WA	Dorre Island	-25.08333333	113.1083
WAM		A14961	WA	Dorre Island	-25.08333333	113.1083
WAM		A14962	WA	Dorre Island	-25.08333333	113.1083
WAM		A14963	WA	Dorre Island	-25.08333333	113.1083
WAM		A14964	WA	Day Dawn	-27.46527778	117.8625
WAM		A14965	WA	Day Dawn	-27.46527778	117.8625
WAM		A14967	WA	Day Dawn	-27.46527778	117.8625
WAM		A14968	WA	Day Dawn	-27.46527778	117.8625
WAM		A14969	WA	Point Cloates	-22.69722222	113.6986
WAM		A14970	WA	Waddalynia Rock Hole [15 km SW of Rawlinna rlwy stn]	-31.09027778	125.2194
WAM		A16137	WA	Great Sandy Desert	-22.88333333	121.95
WAM		A16138	WA	Lake Auld Great Sandy Desert	-22.5	123.85
WAM		A16139	WA	Lake Auld Great Sandy Desert	-22.5	123.85

WAM		A16256	WA	Lake Cronin	-32.3875	119.7583
WAM		A16399	WA	Bendering Reserve trapline 1	-32.37361111	118.3736
WAM		A16610	WA	1 km NNE of Mangrove Bay	-21.96111111	113.9486
WAM		A17752	WA	South End of Bush Bay	-25.225	113.8486
WAM		A17753	WA	ca 10 km SSE of Greenough Point	-25.08194444	113.7111
WAM		A17754	WA	Long Point	-25.47222222	113.9611
WAM		A19547	WA	Fisheries Rd 20 km E of Baring Rd CANP	-33.71944444	123.4069
WAM		A19548	WA	20 km WSW of Israelite Bay	-33.69583333	123.6986
WAM		A1956	WA	Mt Donnelly [= Donnelly River ??]	-34.1	115.9833
WAM		A1957	WA	Mt Donnelly [= Donnelly River ??]	-34.1	115.9833
WAM		A1958	WA	Mt Donnelly [= Donnelly River ??]	-34.1	115.9833
WAM		A1959	WA	nr Mt Donnelly [= Donnelly River ??]	-34.08333333	116
WAM		A1960	WA	Mt Donnelly [= Donnelly River ??]	-34.1	115.9833
WAM		A1961	WA	Monigup Pass near Toolbrunup	-34.36944444	118.075
WAM		A19746	WA	1 km E of Loongana	-30.94583333	127.05
WAM		A19747	WA	16 km S of Haig	-31.13194444	126.1417
WAM		A19940	WA	3 km NNE of Israelite Bay	-33.59166667	123.8764
WAM		A20679	WA	Near Milgy Spring 22 km SW of Barnong HS	-28.75	116.15
WAM		A2415	WA	Gnowangerup	-33.94444444	118.0083
WAM		A2427	WA	Woolundra	-31.62361111	117.7875
WAM		A2428	WA	Woolundra	-31.62361111	117.7875
WAM		A2448	WA	Dirk Hartog Island	-25.62777778	112.9931

WAM		A2845	WA	Toolbrunup SE Tambellup	-34.36666667	118.05
WAM		A539	WA	Cape Riche	-34.61111111	118.7528
WAM		A6555	WA	Mouth of Wooramel River	-25.84861111	114.275
WAM		A6895	WA	Mt Barren area	-34.2	119.425
WAM		A6897	WA	Mt Barren area	-34.2	119.425
WAM		A6898	WA	Mt Barren area	-34.2	119.425
WAM		A8352	WA	Peron Peninsula	-25.85277778	113.5833
WAM		A8547	WA	Dorre Island	-25.08333333	113.1083
WAM		A8548	WA	Dorre Island	-25.08333333	113.1083
WAM		A8549	WA	Dorre Island	-25.08333333	113.1083
WAM		A8550	WA	Dorre Island	-25.08333333	113.1083
WAM		A8551	WA	Dorre Island	-25.08333333	113.1083
WAM		A8552	WA	5 miles N of Hines Hill	-31.46944444	118.05
WAM		A8553	WA	7 miles S of Knobby Head N of Jurien Bay	-29.75555556	114.975
WAM		A8554	WA	On mainland opposite Green Islets	-30.68194444	115.1458
WAM		A8555	WA	Learmonth	-22.23333333	114.1056
WAM		A8556	WA	Point Cloates	-22.69722222	113.6986
WAM		A8557	WA	Yardie Creek Station	-21.88472222	114.0125
WAM		A8558	WA	Dotharola Wooralapooka Well Ningaloo Station	-22.65	113.8667
WAM		A8559	WA	Yardie Creek Station NW of HS	-21.88472222	114.0125
WAM		A8994	WA	Dorre Island	-25.08333333	113.1083
WAM		A8995	WA	Lake Gardner	-34.95694444	118.1514
WAM		A9362	WA	Nannup	-33.9625	115.7417
WAM		A9696	SA	6 miles S of Kingoonya	-30.98333333	135.3667
WAM		A9718	WA	49 miles [=79 km] SE of Rawlinna	-31.48333333	125.7333
WAM		A9848	WA	70 miles NE of Rawlinna	-30.42638889	125.9917

SAM	SAM - general collection	B19951	SA	near Second Valley	-35.53333333	138.2333
SAM	SAM - general collection	B2266	SA	Devils Village Lake Callabonna area	-29.5	139.9
SAM	SAM - general collection	B23090	SA	Port Augusta	-32.49166667	137.75
SAM	SAM - general collection	B23267	SA	Goolwa	-35.50833333	138.7583
SAM	SAM - general collection	B23268	SA	Marree	-29.65	138.0667
SAM	SAM - general collection	B23446	SA	Stansbury Yorke Peninsula	-34.90833333	137.7917
SAM	SAM - general collection	B27915	SA	Myrtle Springs	-30.35	138.2667
SAM	SAM - general collection	B28388	SA	Encounter Bay	-35.56666667	138.6
SAM	SAM - general collection	B28389	SA	Kuitpo	-35.18333333	138.6833
SAM	SAM - general collection	B31129	SA	ESE of Gosse Hill Mt Rescue Conservation Park	-35.94444444	140.3694
SAM	SAM - general collection	B33581	SA	Goolwa	-35.50833333	138.7583
SAM	SAM - general collection	B345	SA	Kallioota SA	-31.83333333	137.9167
SAM	SAM - general collection	B36823	SA	Port Davis SW Port Pirie	-33.23333333	137.9333
SAM	SAM - general collection	B4355	SA	Goolwa	-35.50833333	138.7583

SAM	SAM - general collection	B4356	SA	Goolwa	-35.50833333	138.7583
SAM	SAM - S.A. White Collection	B53153	SA	S[W] of Port Augusta	-32.6	137.7583
SAM	SAM - S.A. White Collection	B53154	SA	East Well Gawler Ranges	-32.45694444	136.1236
SAM	SAM - S.A. White Collection	B53155	SA	Lake Dempsey W of Port Augusta	-32.46666667	137.7292
SAM	SAM - S.A. White Collection	B53156	SA	Albert Hill Lake Albert District	-35.54444444	139.3625
SAM	SAM - S.A. White Collection	B53157	SA	Meningie	-35.68333333	139.3542
SAM	SAM - S.A. White Collection	B53159	SA	Albert Hill Lake Albert District	-35.54444444	139.3625
SAM	SAM - S.A. White Collection	B53160	SA	foot of Marble Range Eyre Peninsula	-34.39027778	135.4889
SAM	SAM - S.A. White Collection	B53161	SA	Albert Hill Lake Albert District	-35.54444444	139.3625
SAM	SAM - S.A. White Collection	B53162	SA	Albert Hill Lake Albert District	-35.54444444	139.3625

SAM	SAM - S.A. White Collection	B53163	SA	Albert Hill Lake Albert District	-35.54444444	139.3625
SAM	SAM - S.A. White Collection	B53168	SA	40 miles W of Oodnadatta	-27.56666667	135
SAM	SAM - S.A. White Collection	B53169	SA	40 miles W of Oodnadatta	-27.56666667	135
SAM	SAM - general collection	B55506	SA	Mahanewo Stn Gairdner Torrens Basin	-31.71666667	136.4
SAM	SAM - general collection	B55857	SA	68 km WNW Yalata	-31.38777778	131.1558
SAM	SAM - general collection	B55887	SA	Wire Creek Bore Macumba Station	-27.26055556	135.5072
SAM	SAM - general collection	B56064	SA	ca 3 km W of Buckinna Hill on road between Cowarie HS & Mirra Mitta Bore	-27.70833333	138.5889
SAM	SAM - Eckert Collection	B57584	SA	'Belacre' 10 miles SE of Meningie	-35.80166667	139.4678
SAM	SAM - Eckert Collection	B57585	SA	14 miles NE of Arno Bay	-33.78333333	136.75
SAM	SAM - Eckert Collection	B57589	SA	Cape Spencer Yorke Peninsula	-35.26777778	136.8847
SAM	SAM - Eckert Collection	B57591	SA	Daly Head Yorke Peninsula	-35.01861111	136.9192
SAM	SAM - Eckert Collection	B57594	SA	Myrtle Springs 10 miles SW of Lyndhurst	-30.38333333	138.2667

SAM	SAM - Eckert Collection	B57595	SA	27 Km E Lyndhurst	-30.2	138.6
SAM	SAM - Eckert Collection	B57596	SA	27 Km E Lyndhurst	-30.2	138.6
SAM	SAM - Eckert Collection	B57597	SA	27 Km E Lyndhurst	-30.2	138.6
SAM	SAM - Eckert Collection	B57600	SA	3 miles S of Lyndhurst	-30.33333333	138.35
SAM	SAM - Eckert Collection	B57601	SA	24 km N of Mannahill on Weekaroo Rod	-32.28472222	140.0183
SAM	SAM - Eckert Collection	B57603	SA	1 km E of Mt Lyndhurst Station	-30.16916667	138.7019
SAM	SAM - Eckert Collection	B57605	SA	Near Mt Barry 1 mile NW of Camel Ck Crossing near Oodnadatta	-28.36666667	134.7167
SAM	SAM - Eckert Collection	B57609	SA	Pandurra Eyre Peninsula	-32.63333333	137.4333
SAM	SAM - Eckert Collection	B57610	SA	4 km NW of Tombstone Hill Plumbago Olary Plains	-32.05	139.8833
SAM	SAM - Eckert Collection	B57611	SA	Point La Batt Eyre Peninsula SA	-33.15027778	134.2517
SAM	SAM - Eckert Collection	B57613	SA	8 miles E Port Augusta	-32.5	137.8833
SAM	SAM - Eckert Collection	B57614	SA	8 Miles East Pt. Augusta	-32.5	137.8833
SAM	SAM - Eckert Collection	B57615	SA	Redcliffe Station Flinders Ranges SA	-33.70194444	139.5358
SAM	SAM - Eckert Collection	B57618	SA	10 miles N of Tutye Vic	-35.08333333	141.4333

SAM	SAM - Eckert Collection	B57619	Vic	12 miles N of Tutye	-35.06666667	141.45
SAM	SAM - Eckert Collection	B57623	SA	Wanna Eyre Peninsula	-34.88527778	135.8522
SAM	SAM - Eckert Collection	B57625	SA	5 miles nth of Wharminda	-33.88333333	136.2333
SAM	SAM - Eckert Collection	B57626	SA	6.5 miles nth of Wharminda	-33.86666667	136.2167
SAM	SAM - Eckert Collection	B57627	SA	Whyalla	-33.03388889	137.5681
SAM	SAM - Eckert Collection	B57629	SA	a few miles S of Yatina Dam on Mt Victor Road Melton Station	-32.33583333	139.6025
SAM	SAM - general collection	B58612	SA	ca 2km N Warbler [=Warbla] Cave Nullarbor Plain	-31.50833333	129.1069
SAM	SAM - general collection	B7546	SA	Coralbignie Gawler Ranges	-32.61666667	136.3583
SAM	SAM - general collection	B7547	SA	Mt Ive SA	-32.43333333	136.0667
SAM	SAM - general collection	B7548	SA	Bollaparudda Creek ca 20 miles W of Port Victor	-35.61666667	138.4
SAM	SAM - general collection	B7551	SA	Oodnadatta	-27.53888889	135.4389

Appendix 2. Location data for specimens used in the genetic analyses.

(a) Calamanthus campestris

Catalogue Number	Institution	Locality	Latitude	Longitude	Event Date
24638	ABTC SA Museum	Central Northern South Australia, Lagoon Waterhole, 14 km. E. of Wth./Mabel Creek Stn.	-29.1667	134.25	
38771	Museum Victoria	Murrayville, Victoria	-35.5333	141.1833	
119456	ABTC SA Museum	26k N Cook turn-off on Eyre highway	-31.3237	130.4865	
128421	ABTC SA Museum	Central Northern SA, Wire Creek Bore	-27.2606	135.5072	
148422	ABTC SA Museum	North-East SA, Fossil Bore, ca 30 km E Moolawatana Stn	-29.8767	140.1175	
A36904		Typographical error: = A39704			
A38995	WAM	12.8 km N of Sandy Pt - Brows Hollow track, Dirk Hartog Island	-25.6273	112.989	17/09/2014
A38996	WAM	ca 18 km N of Leeman	-29.7849	114.967	21/09/2014
A38997	WAM	near rubbish tip, ca 6 km SE of Steep Point	-26.1821	113.2016	21/09/2014
A38998	WAM	12.8 km N of Sandy Pt - Brows Hollow track, Dirk Hartog Island	-25.6273	112.989	17/09/2014
A39000	WAM	small bay SE of Herald Bay, Dirk Hartog Island	-25.8806	113.1331	15/09/2014
A39704	WAM	Dorre Island	-25.0833	113.1083	8/08/2016
B31752	ANWC	Toompup South Road, 36 km S of Ongerup/Gnowangerup Road	-34.2781	118.5214	27/11/1999
B31816	ANWC	15 km N of Ravensthorpe	-33.4703	120.0197	29/11/1999
B40174	ANWC	17 km N of Lyndhurst	-30.1333	138.2833	12/09/1985
B40195	ANWC	17 km n of Lyndhurst	-30.1333	138.2833	14/09/1985
B40214	ANWC	144 km NE of Coober Pedy on rd to Oodnadatta; Goorikianna Ck, 30 km NE of Arckaringa Creek	-27.8667	135.0333	17/09/1985
B40215	ANWC	144 km NE of Coober Pedy on rd to Oodnadatta; Goorikianna Ck, 30 km NE of Arckaringa Creek	-27.8667	135.0333	17/09/1985
B40451	ANWC	E of Murrayville, just E of Cowangie	-35.2333	141.3833	9/10/1985
B46656	ANWC	C.15 km N of Stirling North, NNE of Port Augusta; Emeroo Station	-32.4167	137.8333	27/10/1994
B46657	ANWC	C.15 km N of Stirling North, NNE of Port Augusta; Emeroo Station	-32.4167	137.8333	27/10/1994
B48318	ANWC	C.17 km W of Yappala Station H'stead,c.25 km NW of Hawker	-31.8122	138.2739	2/09/1996

B48320	ANWC	C.17 km W of Yappala Station H'stead,c.25 km NW of Hawker	-31.8122	138.2739	2/09/1996
B48327	ANWC	Yadlamalka Station, c.50 km N of Port Augusta	-31.9772	137.9739	2/09/1996
B48328	ANWC	Yadlamalka Station, c.50 km N of Port Augusta	-31.9772	137.9739	2/09/1996
B49966	ANWC	Riddles Heath, c.20 km ENE of Meningie	-35.6069	139.5222	9/04/1999
B49967	ANWC	Riddles Heath, c.20 km ENE of Meningie	-35.6069	139.5222	9/04/1999
B51797	ANWC	26 km N of Cook turn-off on Eyre Highway	-31.3237	130.4865	26/07/2007
B54401	ANWC	52 km SE of Rawlinna Station homestead, Nullarbor Plain	-31.4036	125.5053	18/08/2008
Z38794	Museum Victoria	Arkaringa Creek (Akeringa Creek *37º 11' S *140º 01' E)	-30.5	139.7167	

(b) Calamanthus fuliginosus

Catalogue Number	Institution	Locality	Latitude	Longitude	Event Date
18310	ABTC SA Museum	Beachport, SA	-37.475	140.02	
70593 (B49253)	ABTC SA Museum	South-East South Australia, Bald Hill, 2.1 km SSW			
24252_F_ B42616	ABTC SA Museum	Big Heath, Naracoorte	-37.08	140.567	
B38186	ANWC	SE of Sassafras, 1 km N of Tianjara	-35.1667	150.3	5/04/1984
B38188	ANWC	SE of Sassafras, 1 km N of Tianjara	-35.1667	150.3	5/04/1984
B38189	ANWC	SE of Sassafras, 1 km N of Tianjara	-35.1667	150.3	5/04/1984
B38940	ANWC	Strahan aerodrome	-42.15	145.3	17/03/1985
B40404	ANWC	West Range Road, N of Kingston	-36.7333	139.8833	4/10/1985
B40406	ANWC	West Range Road, N of Kingston	-36.7333	139.8833	5/10/1985
B40407	ANWC	West Range Road, N of Kingston	-36.7333	139.8833	5/10/1985
B40408	ANWC	West Range Road, N of Kingston	-36.7333	139.8833	5/10/1985
B44866	ANWC	Cape Conran, 26 km ESE of Orbost	-37.8031	148.7242	21/06/1993
B45323	ANWC	Rushy Lagoon Station, c.12 km N of Gladstone	-40.8317	147.9589	10/11/1993
B45324	ANWC	Rushy Lagoon Station, c.12 km N of Gladstone	-40.8317	147.9589	10/11/1993
B45326	ANWC	Rushy Lagoon Station, c.12 km N of Gladstone	-40.8317	147.9589	10/11/1993

B45393	ANWC	Rushy Lagoon Station, c.12 km N of Gladstone	-40.8958	147.9633	11/11/1993
B45412	ANWC	Petal Point, c.21 km N of Gladstone	-40.7817	147.945	12/11/1993
B45986	ANWC	Lake Burbury, 22 km E of Queenstown; old highway	-42.1281	145.6478	4/12/1993
B46135	ANWC	Princetown area, between Lower Gellibrand R and Pt Campbell	-38.6833	143.1333	28/05/1994
B46136	ANWC	Princetown area, between Lower Gellibrand R and Pt Campbell	-38.6833	143.1333	28/05/1994
Z38782	Museum Victoria	NSW, Morton National Park	-35.2333	150.2	
Z38799	Museum Victoria	TAS, Strahan	-42.15	145.3167	

(c) Hylacola cauta

Catalogue Number	Institution Code	Locality	Latitude	Longitude	Event Date
11930					
72917	Museum Victoria	Western Australia, Lake King, 28km east on Norseman Rd (33 05 S, 119 59 E)	-33.08	119.98	
72918	Museum Victoria	Western Australia, Lake King, 28km east on Norseman Rd (33 05 S, 119 59 E)	-33.08	119.98	
119679	ABTC SA Museum	Maralinga airstrip	-30.17	131.6233	
119680	ABTC SA Museum	Maralinga airstrip	-30.17	131.6233	
119728	ABTC SA Museum	Yellabinna area, 96.6k NNE Ceduna	-31.4764	133.9558	
119729	ABTC SA Museum	Yellabinna area, 96.6k NNE Ceduna	-31.4764	133.9558	
119897	ABTC SA Museum	Maralinga airstrip	-30.17	131.6233	
B31790	ANWC	33 km e of lake king	-33.0786	120.0122	28/11/1999
B40337	ANWC	Sinclairs Gap, Middleback Range, W of Whyalla, Eyre Peninsula	-33.1	137.1417	27/09/1985
B40352	ANWC	Sinclairs Gap, Middleback Range, W of Whyalla, Eyre Peninsula; western side of Sinclairs Gap	-33.1333	137.1167	28/09/1985
B40353	ANWC	Sinclairs Gap, Middleback Range, W of Whyalla, Eyre Peninsula; western side of Sinclairs Gap	-33.1333	137.1167	28/09/1985
B40441	ANWC	51 km N of Pinnaroo, Sunset Country	-34.8833	141.05	7/10/1985
B40442	ANWC	51 km N of Pinnaroo, Sunset Country	-34.8833	141.05	7/10/1985

B40443	ANWC	Comet Bore, c.55 km N of Bordertown, Ngarkat Conservation Park	-35.7333	140.8	7/10/1985
B40444	ANWC	Comet Bore, c.55 km N of Bordertown, Ngarkat Conservation Park	-35.7333	140.8	7/10/1985
B40630	ANWC	10 km SSW of Chapman's Bore, near Tailem Bend	-35.1625	139.5583	9/10/1986
B42453	ANWC	3 km S of Chapman's Bore, 22 km E of Murray Bridge	-35.15	139.55	7/11/1989
B42617	ANWC	Western River Conservation. Park, Stokes Bay, Kangaroo Island; track into waterfall creek	-35.7167	136.9	13/11/1989
B42625	ANWC	Western River Conservation. Park, Stokes Bay, Kangaroo Island; between Billy Goat/Castle Gullies	-35.6917	136.9167	14/11/1989
B49512	ANWC	Round Hill Nature Reserve, c.30 km SE of Mount Hope	-32.9908	146.1094	21/10/1997
B49513	ANWC	Round Hill Nature Reserve, c.30 km SE of Mount Hope	-32.9908	146.1094	21/10/1997
B49514	ANWC	Round Hill Nature Reserve, c.30 km SE of Mount Hope	-32.9908	146.1094	21/10/1997
B49622	ANWC	Buddigower Nature Reserve, c.18 km SW of West Wyalong	-34.0167	147.085	10/11/1998
B49623	ANWC	Buddigower Nature Reserve, c.18 km SW of West Wyalong	-34.0167	147.085	10/11/1998
B49624	ANWC	Buddigower Nature Reserve, c.18 km SW of West Wyalong	-34.0167	147.085	10/11/1998
B49625	ANWC	Buddigower Nature Reserve, c.18 km SW of West Wyalong	-34.0167	147.085	10/11/1998
B52171	ANWC	Maralinga airstrip	-30.17	131.6233	
B52186	ANWC	Maralinga airstrip	-30.17	131.6233	8/08/2007
B52187	ANWC	Maralinga airstrip	-30.17	131.6233	8/08/2007
B52260	ANWC	Yellabinna area, 96.6 km NNE of Ceduna	-31.4764	133.9558	12/08/2007
B52261	ANWC	Yellabinna area, 96.6 km NNE of Ceduna	-31.4764	133.9558	12/08/2007
B52269	ANWC	Yellabinna area, NNE of Ceduna	-31.5031	133.8825	
Z2919	Museum Victoria	Western Australia, Lake King, 28km east on Norseman Rd (33 05 S, 119 59 E)	-33.08	119.98	
Z2920	Museum Victoria	Western Australia, Grass Patch, 5km north (33 10 S, 121 43 E)	-33.17	121.72	
Z2921	Museum Victoria	Western Australia, Grass Patch, 5km north (33 10 S, 121 43 E)	-33.17	121.72	
Z2924	Museum Victoria	Victoria, Big Desert State Forest (35 23 S, 141 10 E)	-35.38	141.17	

(d) Hyacola pyrrhopygia

Catalogue	Institution	Locality	Latitude	Longitude	Event Date

Number					
B24447	ANWC	Pigeon House Mountain, W of Milton	-35.3333	150.2667	20/02/1985
B38783	ANWC	Pigeon House Mountain, W of Milton	-35.3333	150.2667	25/02/1985
B38785	ANWC	Pigeon House Mountain, W of Milton	-35.3333	150.2667	19/02/1985
70458	ABTC SA Museum	Flinders Ranges, Telowie Gorge, 1.5 km N	-33.0333	138.1167	