

# How homogeneous is West Coast Renosterveld? Implications for conservation

I.P. NEWTON\* and R.S. KNIGHT\*\*

**Keywords:** cluster analysis, conservation, extinction, fragmentation, homogeneity, South Africa, West Coast Renosterveld

## ABSTRACT

In this paper, we test two published assumptions about West Coast Renosterveld, a highly fragmented vegetation type in South Africa. The first is that it is a homogeneous vegetation type. The second is that small fragments are subsets (in terms of species) of the larger fragments. We used three sets of data. Species lists showed that more than 44 % of the species identified at 16 sites were unique to that site. Examining the dominant and rare species occurring at subsites within large fragments showed that, on average three-quarters, and never less than half, of the species were confined to one subsite. Analyses of rare and endangered plant species lists showed that the average distance separating patches of the same species was almost 30 km. Only 36.4 % of the rare or endangered species localities coincided with a major (> 25 ha) fragment. Our first conclusion was that many endemic species are constrained by micro- or meso-habitat demands that are not immediately obvious to the observer, and hence the vegetation should not be considered locally homogeneous. Our second conclusion was that the smaller fragments (< 25 ha) are of importance for the conservation of West Coast Renosterveld plant species.

## INTRODUCTION

West Coast Renosterveld (WCR) is arguably the most highly transformed vegetation type within South Africa (Reyers *et al.* 2001; Rouget *et al.* 2003), with between 5 % (Von Hase *et al.* 2003) and 9.4 % (Newton & Knight 2005) remaining. Despite this, Rebelo (1995) observed that when species lists from the 1700s and from today were compared, no extinctions had been reported. One of the three suggestions that he made as to the reason for this, was that renosterveld was homogeneous, and localized endemic species were therefore rare or absent. As a corollary, he suggested that this would imply that even rare species would have a wide distributional range within specialized habitats. Bond & Goldblatt (1984), and Kemper *et al.* (1999), have both suggested that coastal renosterveld is home to many local endemics, with Von Hase *et al.* (2003) recording 132 such species from the Boland/Swartland Coastal Renosterveld Broad Habitat Units (BHU) (Cowling & Heijnis 2001). Von Hase *et al.* (2003) in their conservation plan for coastal renosterveld, rightly observed that due to its fragmented nature, only a limited number of fragments could be financially conserved. However, they also made the assumption that the smaller fragments were merely subsets of the major fragments, and that by conserving the larger fragments, one was effectively conserving most species. We set out to test these assumptions, using three sets of data. WCR was divided by Cowling & Heijnis (2001) into two major habitat units, and it has recently been further subdivided into five subtypes (Mucina & Rutherford 2004). Since management plans were designed around this vegetation type as an entity (Von Hase *et al.* 2003), we are restricting our examination to the single, larger, more recognized unit. Figure 1 shows the location of the sites mentioned in the text.

## METHODS

Three sets of data were used to estimate the level of homogeneity within WCR. In the first case, species lists, mainly from published sources, were used (Table 1). The data were entered into an EXCEL spreadsheet, their taxonomy checked (Harvey & Sonder 1859–1860, 1894a, b; Thiselton-Dyer 1896, 1897, 1904, 1909, 1912, 1913, 1925; Gibbs Russell *et al.* 1985, 1987, 1990; Arnold & De Wet 1993; Goldblatt & Manning 2000; Germishuizen & Meyer 2003) and aliens excluded. In total, 1 510 indigenous species were identified. Forty-four other species could not be traced to recent taxonomic works and were excluded from the analyses.

To determine plant-community relationships between the different sites, resemblance matrices for each of three groups (see below) were constructed using the Sorenson Coefficient method. This method ignores 0–0 similarities when performing pair-wise comparisons, and doubly weights 1–1 agreements. The presence of a species in a pair of sites counts as a definite similarity, whereas its absence may be due to a genuine absence, or to collecting effort. The sites were clustered using the 'unweighted pair-group method using arithmetic averages' (UPGMA) as described in Romesburg (1984). Distortions introduced by the clustering method were tested by using the cophenetic correlation coefficient (Romesburg 1984). Twenty-one sites were analysed. For the first analysis, the data were divided into five individual sites plus two regional sites (Darling and Southwest), these two regional groupings consisting of sites located close together and predominantly of the same substrate type (granite for Darling, shale for Southwest). The individual sites within each of the two regional groups of the first analysis were then analysed separately to determine site relationships within those groups. Ten sites made up the Darling region and six the Southwest region.

The second set of data used was that collected by the Botanical Society during their Lowland Renosterveld Conservation project. This data set was analysed on a simple number of species/unique species per site or

\* Correspondence author. Current address: Department of Archaeology, University of Cape Town, Rondebosch, 7700, Cape Town. e-mail: ian.newton@uct.ac.za.

\*\* Department of Biodiversity and Conservation Biology, University of the Western Cape, Private Bag X17, Bellville 7530, Cape Town. MS. received: 2008-10-02.

TABLE 1.—Species lists used for cluster analyses

Site	Author(s)	Type and quality
Blouberg	Tansley 1982	Very superficial
Darling Hills	Heydenrych & Littlewort 1995	Authors estimated a 13 % error
Dassenberg and Klein Dassenberg	Kilian 1995	Amalgamation 'relatively good, but missing many species'
Eensaamheid	McDowell 1995	Detailed study; good
Elandsberg PNR	Mrs Elizabeth Parker	Private list; detailed
Paarlberg	Prof. Suzanne Milton	Private amalgamation; good
Signal Hill	Joubert & Moll 1992	Detailed study + other published lists; good
Stellenbosch	Duthie 1930	Detailed study; good
Stellenbosch	Levyns 1929	1 022 m <sup>2</sup> site; good within site
Tienie-Versfeld Reserve	Hilton-Taylor 1993*	NBI field excursion list; reasonable
Tygerberg, Meerendal, Hoogekraal and Kanonkop	Wood & Low 1993	Amalgamation; good
Voelvlei	Tansley 1982	Very superficial

\* List reproduced in Heydenrych & Littlewort 1995.

subsite. The third set of data was that maintained by the CREW (Custodians of Rare and Endangered Wildflowers) project. These data record the locations and environmental conditions of rare and endangered plant species. The average distance between populations of the same species or subspecies was calculated, using the coordinates supplied, and the theorem of Pythagoras. An average great-circle distance per degree of 92.7 km E–W and 111.2 km N–S, being that of 33.5°S and 18.5°E, was used. Variations in these distances over the area examined would be insignificant when compared to species location errors and undulations of the earth. Finally the locations were plotted on a map of the remaining fragments of > 3 ha and > 25 ha (Newton & Knight 2005), and the number of species coinciding with these assessed.

## RESULTS

Based upon published data, Table 2 suggests that there is a very high level of local endemism within each of the sites analysed. In the all-areas analysis, only three species were common to all seven sites, and 52.3 % of the species were confined to single sites. Looking at the Southwest region, half the species were again confined to single sites, and only seven were found at all six sites. The Darling region showed a slightly lower proportion of species confined to one site (44.5 %) and eight species occurred in all ten sites. The cluster tree (Figure 1) shows the relationship of the sites to one another. The main grouping (Figure 2A) reflects the high level of endemism indicated in Table 2. The two most similar sites are the two regional sites, which, since they consist of 16 subsites, might be expected to contain a

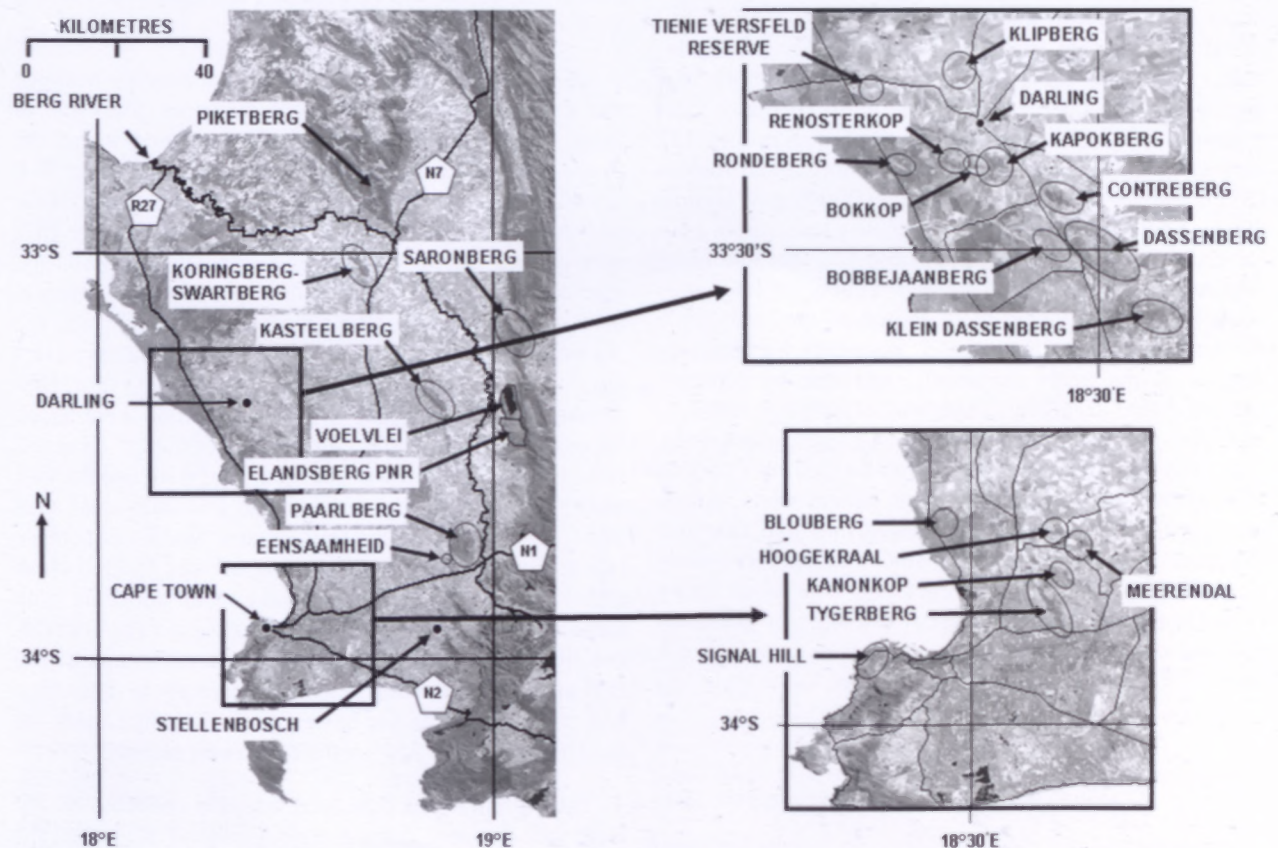


FIGURE 1.—Map of region showing sites referred to in text and tables.

TABLE 2.—No. and percentage of plant species common to study sites used for preliminary assessment of diversity of West Coast Renosterveld

	All		Southwest		Darling	
	No.	%	No.	%	No.	%
Total no. sites	7		6		10	
Species common to all 10 sites	-	-	-	-	8	1.2
Species common to any 9 sites	-	-	-	-	26	4.1
Species common to any 8 sites	-	-	-	-	17	2.7
Species common to any 7 sites	3	0.2	-	-	23	3.6
Species common to any 6 sites	30	2.0	7	1.0	31	4.8
Species common to any 5 sites	61	4.0	30	4.4	33	5.1
Species common to any 4 sites	99	6.6	68	10.0	42	6.6
Species common to any 3 sites	192	12.7	96	14.2	58	9.0
Species common to any 2 sites	336	22.3	139	20.5	118	18.4
Species found at only 1 site	1 025	52.3	338	49.9	285	44.5
Total no. species	1 510		678		641	

large number of shared species. In the Southwest region (Figure 2B), the two features to note are that Signal Hill is more closely clustered with the Tygerberg than are Meerendal and Hoogekraal (which are physically closer to Tygerberg), and the distant positioning of Blouberg. In the Darling region (Figure 2C), the similarities between the hills were generally higher than elsewhere.

The three sites showing the greatest similarity (Bokkop, Renosterkop and Kapokberg) lie adjacent to each other and have a similar linear extent (NW to SE) as the Tygerberg. The Dassenberg and Klein Dassenberg form a separate group, probably because of their mixed geological origins, and hence floristic community possibilities. Note the outlying Tienie Versfeld Reserve, which

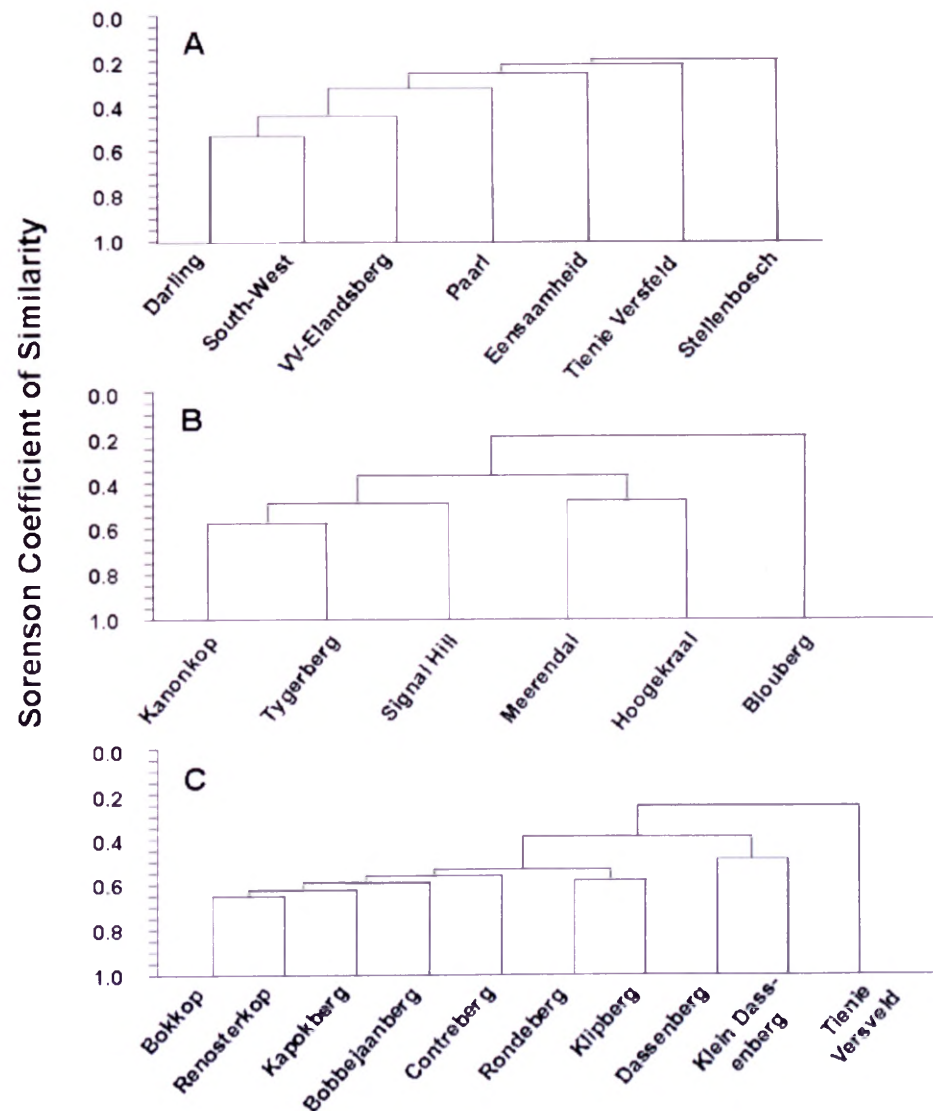


FIGURE 2.—Cluster analyses showing species community relationships between sites for which species lists were available. A, major sites; B, sites from Southwest region; C, sites from Darling region.

will be discussed later. The cophenetic correlation coefficients ( $r$ ) for the three groups ranged between 0.94 and 0.97, indicating that there was very little distortion introduced during the clustering process (Romesburg 1984).

With respect to the lowlands renosterveld data collected by the Botanical Society, the results supported the findings described above. Of the 135 fragments sampled, 114 were described as renosterveld, and the analyses were confined to these. Two hundred and fifty-four indigenous species were listed, 109 of which (42.9 %) were found only at one site. Two hundred and nine species (82.3 %) were found at five or less sites. Only five species were found at more than twenty sites, these being *Eriocephalus africanus* (72 sites), *Elytropappus rhinocerotis* (69 sites), two species of *Ehrharta* (*thunbergii* and *calycina*) at 41 and 36 sites respectively, and *Cotula turbinata* at 26 sites.

In the CREW endangered species data list, 1 448 records of 184 species distributed over 1 037 unique sites were used. Thirty-two species were recorded from single sites only, and 102 species (55.4 %) were found at five or less localities. However, 18 species were found at twenty or more sites, and one species was found at 51 localities. When the distribution of species occurring at more than one site was examined, it was noted that they tended to be well distributed across the whole WCR region, rather than being clustered together. Table 3 provides a summary of average distances between populations of the same species, within eight classes, where a species occurred at two or more localities. The first item to note is that median distances between populations are similar to average distances, thus showing that the average distances, with the possible exception of the species occurring at two sites only, have not been distorted by one abnormally large or small distance. It should be noted that the populations of six of the 15 species with only two site records were separated by more than 20 km. The second point of interest is that there is no absolute pattern indicating that the more common species are, on average, more widely, or narrowly distributed than those species for which there are only two or three records. On the other hand, classes with more species do tend to have their most distant populations at a greater distance from each other, as one would expect when fitting more localities into a fixed area, while keeping average distance similar. Four hundred and seventy-four of 1 044 (45.4 %) locations recorded

fell within fragments of > 3 ha identified by Newton & Knight (2005), whereas 380 (36.4 %) coincided with a fragment of > 25 ha. It has been suggested that fragments need to be 25 ha or larger in order to maintain a reasonable semblance of ecological integrity (Donaldson *et al.* 2002).

## DISCUSSION

A number of objections can be raised about the validity of the results presented here. We will try to answer some of these below, but we believe that the queries raised, while important in themselves, do not nullify the object of our paper. The first query raised is the quality of the data. With the exception of Blouberg, and possibly the Tienie Versfeld Reserve, all the sites have been sampled by one or more competent botanist at an intensity that would be acceptable for the institution of management plans or a post graduate degree.

The second problem is that a number of the fragments sampled were not edaphically homogeneous and were adjacent to, or incorporated fynbos (e.g. Paarlberg, Elandsberg). Plant collections at these sites have been predominantly carried out in terms of the site, rather than the soil type upon which the species collected was found. While this will obviously create differences between the sites, the question we are asking here is, how many species does this site have in common with the other sites? If renosterveld has a high level of homogeneity, there should be a relatively large number of species that are common to all sites, irrespective of additional species from adjacent vegetation types. Table 2 shows that this is not the case. To demonstrate our basic premise we give two examples of sites of similar geology, situated close together. We will take the three closest (in space as well as in species composition) sites in the Darling area and the Tygerberg and Kanonkop sites in the Southwest area. The Darling sites are all classified as Cape Granite (Anon 1990) at the 1:250 000 scale, and as Swartland Granite Bulb Veld by Mucina & Rutherford (2004). Tygerberg and Kanonkop are both classified as Malmesbury Shale and Swartland Shale Renosterveld, by the same authors. The three sites at Darling shared 30.8 % of their species, and 41.5 % of the species were restricted to one site. The Tygerberg–Kanonkop situation is slightly different, as Kanonkop is much smaller

TABLE 3.—Mensural summary of distribution of rare and endangered species across West Coast Renosterveld

Average separation distance (km) per species, not per individual	No. localities at which species occurs, summarized in each column								Summary of all data (km)			
	2	3	4	5	6	7	8-19	20-51	All	Max.	Min.	Range
Average	18.5	24.8	23.2	34.0	36.9	21.5	35.4	39.0	29.2	39.0	18.5	20.5
sd average	23.27	20.08	15.45	13.94	17.48	11.19	12.6	9.04	15.38	23.3	9.0	14.2
Median	8.1	29.9	24.4	30.3	43.9	19.7	34.2	34.4	28.1	43.9	8.1	35.9
sd median		25.12	17.06	16.29	24.73	12.16	12.8	9.82	16.86	25.1	9.8	15.3
Max.	85.4	35.7	38.9	66.0	68.8	45.6	85.6	115.5	67.7	115.5	35.7	79.8
Min.	0.5	8.8	4.2	3.3	2.8	1.6	0.9	0.2	2.8	8.8	0.2	8.6
Range	84.9	26.9	34.7	62.7	66.0	43.9	84.7	115.3	64.9	115.3	26.9	88.4
N	15	51	17	11	16	9	40	18	177			

sd, standard deviation; N, no. species within each column category.

than the Tygerberg. Nevertheless, 65 species (12.1 % of the total found at the two sites) were restricted to Kanonkop. It is clear from these two examples that our results *are* distorted to a certain extent, by our inability to absolutely define those species that are confined to renosterveld soils. However, we believe that the two examples given, show that our basic premise, namely that there is a great deal of local endemism within WCR, is correct.

One might also raise the question of species that are compatible with both soil types. Should such species be considered in a study such as the one presented here? Local climatic conditions may also have an effect on species composition. For example, Boucher (1995) has suggested that the plant community on the Bottelary Hills, which consists of Malmesbury Shale and Cape Granite, would *revert* to fynbos under the right management regime.

#### Cluster analysis

The cluster diagrams themselves (Figure 2), while showing interesting patterns, do not necessarily give an indication of renosterveld homogeneity. This is because many of the sites are not edaphically homogenous and contain fynbos and thicket species. Differences between the sites might thus be construed as being caused by a variety of non-renosterveld species projected upon a basic renosterveld set of species. This problem has to a large extent been discussed above, and we would once again emphasize that our aim is to show there is not a large underlying set of species common to all sites. In the regional analysis (Figure 2A), four of the sites may be considered to have incorporated a large number of Fynbos species. Only the two regional sites and the Stellenbosch site might be considered to contain predominantly renosterveld species, yet the Stellenbosch site is the most unique site, in terms of species. This is interesting as only species recorded from the 'grey-bush' community of Duthie (1930) and the renosterveld site of Levyns (1929) were used, suggesting a minimal influence of fynbos and thicket species. This difference could be due to the higher rainfall that the area receives, compared to the other sites examined.

Looking at the mixed sites, where fynbos species may predominate in the species lists, about one-third of the species found at the Paarlberg and at Voelvllei–Elandsberg were not found at any of the other sites. The species list of Paarlberg does not differentiate between the lower slopes (considered to be renosterveld), and the higher regions, considered to be fynbos (Low & Rebelo 1996) or Fynbos/Renosterveld Mosaic (Cowling & Heijnis 2001). The mosaic of vegetation types (first author pers. obs.) at Elandsberg similarly meant that assigning a species to a specific vegetation (soil) type was not possible. Although Tansley's (1982) Voelvllei species list (41 indigenous species) was included in the Voelvllei–Elandsberg site, (Voelvllei is geologically more likely to be renosterveld, Anon. 1997), only eight of the 741 species were restricted to Voelvllei. Two of the single-site samples (Eensaamheid [Jan Briers Louw] and Tienie Versfeld Reserve) have had their renosterveld connections disputed (Tansley 1982; Savory 1986).

The Southwest and Darling regions each have a number of sites within a relatively small area. There is a greater level of natural connectivity between the Darling hills than between those of the Southwest sites, which have largely been isolated by urbanization. Both of these regions have been well sampled.

In the Southwest region (Figure 2B) the low sampling intensity of Blouberg (51 species) leaves its associations with the other hills in doubt. Like the Klein Dassenberg, this hill supports renosterveld, thicket and fynbos species (Jarman 1986). The cluster analysis showed the Tygerberg and Kanonkop to be the most closely related sites. The relationship between these two sites was discussed earlier. Signal Hill and Tygerberg (the two largest sites) have been well sampled, suggesting that their high (one-third) levels of local endemism are probably genuine. However, one should note that the Tygerberg is entirely a shale formation, whereas Signal Hill comprises shales, granites and Table Mountain Sandstones (Anon. 1990). Both Meerendal and Hoogekraal showed quite high levels of local endemism despite relatively small (111 and 131 respectively) species lists. The high level of endemism at these two small sites is interesting because these hills are in an area that has been cultivated for three hundred or more years. It suggests that the species present are relatively immune to disturbance.

In the Darling region (Figure 2C), we might exclude the Tienie Versfeld Reserve, the Klein Dassenberg and the Dassenberg, as these three sites have a mixture of soils. The remaining seven hills still had 34.5 % of their species confined to one site, and as shown earlier, the closest sites do not always have the closest affinities.

#### Botanical Society lowlands project and CREW data

Plant lists made during the Renosterveld Lowlands Project were confined to the dominant and rare species (Von Hase *et al.* 2003). Therefore, the observation that only five of the species identified occurred at more than 20 of their sites is important. Despite the general assumption that coastal renosterveld is a vegetation type dominated by a few species, we find that the most common species (*Eriocephalus africanus*) only occurred at 72 (63.2 %) of the 114 sites. The sample sites were more widespread than was the case with the published data, and included small patches. Some of the larger fragments had been sampled at more than one spot, thus allowing one to get an idea of the within-fragment diversity. Taking nine such fragments, it was found that the number of species confined to only one sample site within the fragment ranged between 52.6 % and 87.5 % of the species recorded (Table 4). One needs to take into account that the sampling effort was low, but again, it does suggest that there is a very high level of beta or gamma diversity within WCR.

At first glance, the CREW rare and endangered species data appear to contradict the other analyses. Although by definition uncommon (and one thus assumes locally endemic), Table 3 showed that the populations were widely distributed across the entire WCR landscape. In some instances, even those species for which there were only two or three records were widely separated. Keeping in mind that the bounds of

TABLE 4.—No. species common to each subsample site within fragments that were sampled at two or more localities

Fragment	No. species records per fragment	No. unique species per fragment	No. unique species occurring in each subsample				% in 1 subsample only
			In 1 subsample only	In 2 subsamples only	In 3 subsamples only	In 4 subsamples	
Kapokberg	28	23	19	3	1	-	82.6
Swartberg	28	20	14	4	2	0	70.0
Elandsberg	22	14	8	4	2	-	57.1
Voelvllei	16	13	10	3	-	-	76.9
S Kasteelberg	24	21	18	3	-	-	85.7
N Kasteelberg	28	19	10	9	-	-	52.6
E Piketberg sth	27	24	21	3	0	-	87.5
E Piketberg nth	15	12	9	3	-	-	75.0
Saronberg	29	24	20	3	1	0	83.3

WCR approximates a diamond, 184 km (N–S) by 78 km (E–W), the average distance separating populations of these rare species was often substantial.

How can we explain the apparent contradiction between the CREW data and the other analyses? The subsample data of the lowlands project (Table 4) showed that even within a single large fragment, there was a high level of diversity. It is possible that the diversity of the habitat is much greater, as experienced by the plants, than is often perceived by humans. The establishment of species may also have been influenced by environmental and seasonal factors in existence at the time the fragment was burnt, cleared or otherwise disturbed, with an intensity sufficient to allow a change in community composition. Therefore, although from a gross overview the landscape is dominated by a few shrubs, within which are interspersed a variety of grasses and geophytes, there is great variation in how these are distributed, and micro-habitat and disturbance play a much greater role than is thought. Cowling & Lombard (2002) have suggested that plants of the Cape Floristic Region (CFR) respond to measures of heterogeneity that are more subtle than the coarse variables used in most studies. There may be generalist species, as well as local 'invasions' of species from adjoining fynbos and thicket communities, adding to the unique character of each site. It is likely that the rare and endangered species were, like most other 'true' WCR species, once more common than now, but still confined to particular niches. Due to fragmentation and a breakdown in ecological processes such as pollination, and the spread of seeds by large herbivores, they remain as isolated populations.

#### Conservation action

Cowling *et al.* (1992) showed that there were substantial increases in the number of species recorded as one increased the size of the samples site, within WCR and other CFR vegetation types. Our aim was not to test this, as to a general extent, this would be intuitive. Our aim was to show that there is a great deal of variation in community composition across WCR, and that conserving a few large fragments does not guarantee a high level of conservation of renosterveld endemic species. We have shown that, while there may be a limited

number of species within WCR, and while those species may occur, not only at more than one site, but also at widely distributed sites, the vegetation is not homogeneous at the scale of the remaining fragments.

With the above facts in mind, what should be the next step for the conservation of WCR? We already have a great deal of data, and this is being augmented annually by student projects, professional conservation staff and volunteers guided by CREW. Grantham *et al.* (2008, 2009) have pointed out that there is a trade-off in conservation between data collection and time or money. We would suggest that more than enough basic data have been collected for WCR and the region would benefit from the application of a C-Plan or similar analysis. It will obviously not be possible to save everything *in situ*, but a priority list of the sites for conservation needs to be produced. This will also help the stewardship projects in showing the owners of smaller fragments with endangered species, the unique quality of their particular fragment.

Mucina & Rutherford (2004) have subdivided the original entity of WCR into six units, substantially reducing its presence in what was formerly considered to be one of the primary fragments, namely the Elandsberg Private Nature Reserve. Although this new division will help with the allocation of resources towards conserving examples of each vegetation type, we believe that in the case of WCR, consideration should also be paid to the local climate conditions. Rainfall in particular, increases steeply from the NW to SE (Schulze 1997) and this study has shown that, while the Darling Hills and the Paarlberg are both classified as Swartland Granite Bulb Veld, there is a great deal of difference between the two areas.

#### CONCLUSION

One might conclude that, rather than WCR being home to many *local* endemics, it is home to many widespread *micro-habitat* endemics. Rebelo's (1995) assumption is therefore basically correct, but could be misleading, as the remaining fragments each only contain a small proportion of the species. The implications of this for conservation is that small isolated patches may con-

tain unique species, and the opinion of Von Hase *et al.* (2003), that small fragments are merely subpopulations of the remaining larger extents, is probably incorrect. The larger fragments need to be subsampled at a suitable time of year, to see to what extent the species distribution within each fragment is dependent upon such micro-habitats. If this hypothesis is valid, it is likely to lead to an even greater level of extinction due to climate change than might otherwise be assumed, since corridors proposed for movements across the landscape are likely to be missing many of these micro-habitats.

#### ACKNOWLEDGEMENTS

This material was based upon work supported by the National Research Foundation (NRF) of South Africa under Grant no. 2053674 awarded to Prof. Suzanne J. Milton. The first author acknowledges receipt of a bursary from the NRF. We would also like to thank Domitilla Raimondo for providing us with the CREW and other data from the Botanical Society, Mrs Elizabeth Parker for providing her personal checklist of the flora of the Elandsberg Private Nature Reserve, and Prof. Suzanne Milton for providing her amalgamated checklist of the flora of the Paarlberg. We also thank Richard Cowling and an anonymous referee for their comments.

#### REFERENCES

- ANONYMOUS. 1990. *3318 Cape Town: 1:250 000 Geological Series*. Government Printer, Pretoria.
- ANONYMOUS. 1997. *3319 Worcester: 1:250 000 Geological Series*. Council for Geoscience, Pretoria.
- ARNOLD, T.H. & DE WET, B.C. (eds). 1993. Plants of southern Africa: names and distribution. *Memoirs of the Botanical Survey of South Africa* No. 62: 1–825.
- BOND, P. & GOLDBLATT, P. 1984. Plants of the Cape Flora—a descriptive catalogue. *Journal of South African Botany*, Suppl. 13.
- BOUCHER, C. 1995. Overview on management of Renosterveld. In A.B. Low & F.E. Jones, *The sustainable use and management of renosterveld remnants in the Cape Floristic Region (Proceedings of a Symposium)*: 47–50. FCC Report 1995/4. Flora Conservation Committee, Botanical Society of South Africa, Kirstenbosch, Cape Town.
- COWLING, R.M. & HEIJNIS, C.E. 2001. The identification of Broad Habitat Units as biodiversity entities for systematic conservation planning in the Cape Floristic Region. *South African Journal of Botany* 67: 15–38.
- COWLING, R.M., HOLMES, P.M. & REBELO, A.G. 1992. Plant diversity and endemism. In R.M. Cowling, *The ecology of fynbos: nutrients, fire and diversity*: 62–112. Oxford University Press, Cape Town.
- COWLING, R.M. & LOMBARD, A.T. 2002. Heterogeneity, speciation/extinction history and climate: explaining regional plant diversity patterns in the Cape Floristic Region. *Diversity & Distributions* 8: 163–179.
- DONALDSON, J., NANNI, L., ZACHARIDES, C. & KEMPER, J. 2002. Effects of habitat fragmentation on pollinator diversity and plant reproductive success in Renosterveld shrublands of South Africa. *Conservation Biology* 16.5: 1267–1276.
- DUTHIE, A.V. 1930. List of vascular cryptogams and flowering plants of the Stellenbosch Flats. *Annals of the University of Stellenbosch* 8, sec. A, no. 4: 5–54.
- GERMISHUIZEN, G. & MEYER, N.L. (eds). 2003. Plants of southern Africa: an annotated checklist. *Strelitzia* 14. National Botanical Institute, Pretoria.
- GIBBS RUSSELL, G.E., REID, C., VAN ROOY, J. & SMOOK, L. 1985. List of species of southern African plants, edn 2.1. *Memoirs of the Botanical Survey of South Africa* No. 51: 1–152.
- GIBBS RUSSELL, G.E., WATSON, L., KOEKEMOER, M., SMOOK, L., BARKER, N.P., ANDERSON, H.M. & DALLWITZ, M.J. 1990. Grasses of southern Africa. *Memoirs of the Botanical Survey of South Africa* No. 58: 1–437.
- GIBBS RUSSELL, G.E., WELMAN, W.G., RETIEF, E., IMMELMAN, K.L., GERMISHUIZEN, G., PIENAAR, B.J., VAN WYK, M. & NICHOLAS, A. 1987. List of species of southern African plants, edn 2.2. *Memoirs of the Botanical Survey of South Africa* No. 56: 1–270.
- GOLDBLATT, P. & MANNING, J. 2000. Cape plants. A conspectus of the Cape flora of South Africa. *Strelitzia* 9. National Botanical Institute, Pretoria & Missouri Botanical Garden, St. Louis.
- GRANTHAM, H.S., MOILANEN, A., WILSON, K.A., PRESSEY, R.L., REBELO, T.G. & POSSINGHAM, H.P. 2008. Diminishing return on investment for biodiversity data in conservation planning. *Conservation Letters* 1: 190–198.
- GRANTHAM, H.S., WILSON, K.A., MOILANEN, A., REBELO, T.G. & POSSINGHAM, H.P. 2009. Delaying conservation actions for improved knowledge: how long should we wait? *Ecology Letters* 12: 293–301.
- HARVEY, W.H. & SONDER, O.W. (eds). 1859–1860. *Flora capensis* 1. Reeve, London.
- HARVEY, W.H. & SONDER, O.W. (eds). 1894a. *Flora capensis* 2. Reeve, London.
- HARVEY, W.H. & SONDER, O.W. (eds). 1894b. *Flora capensis* 3. Reeve, London.
- HEYDENRYCH, B.J. & LITTLEWORT, P.E. 1995. *Flora survey of Darling. A preliminary investigation into the conservation of renosterveld remnants in the Darling area*. FCC Report 95/3. Flora Conservation Committee, Botanical Society of South Africa, Kirstenbosch, Cape Town.
- JARMAN, M.L. 1986. *Conservation priorities in lowland regions of the Fynbos Biome*. South African National Scientific Programmes Report No. 87: 1–55.
- JOUBERT, C. & MOLL, E.J. 1992. A phytosociological study of Signal Hill, Cape Town, utilizing both perennial and ephemeral species. *Bothalia* 22: 255–282.
- KEMPER, J., COWLING, R.M. & RICHARDSON, D.M. 1999. Fragmentation of South African renosterveld shrublands: effects on plant community structure and conservation implications. *Biological Conservation* 90: 103–111.
- KILIAN, D. 1995. *Dreams for the Dassenberg: a report on the current status and future options for flora conservation in the Dassenberg–Mamre–Riverlands area*. FCC Report 95/2. Flora Conservation Committee, Botanical Society of South Africa, Kirstenbosch, Cape Town.
- LEVYNS, M.R. 1929. Veld burning experiments at Idas Valley, Stellenbosch. *Transactions of the Royal Society of South Africa* 17: 61–92.
- LOW, A.B. & REBELO, A.G. 1996. *Vegetation of South Africa, Lesotho and Swaziland*. Department of Environmental Affairs and Tourism, Pretoria.
- MCDOWELL, C. 1995. Grazing and renosterveld management. In A.B. Low & F.E. Jones, *The sustainable use and management of renosterveld remnants in the Cape Floristic Region (Proceedings of a Symposium)*: 63–80. FCC Report 1995/4. Flora Conservation Committee, Botanical Society of South Africa, Kirstenbosch, Cape Town.
- MUCINA, L. & RUTHERFORD, M.C. (eds). 2004. *Vegetation map of South Africa, Lesotho and Swaziland: Shapefiles of basic mapping units. Beta version 3.0, January 2004*. National Botanical Institute, Cape Town.
- NEWTON, I.P. & KNIGHT, R.S. 2005. The use of Landsat imagery for the identification of the remaining West Coast Renosterveld fragments, Western Cape Province, South Africa. *South African Journal of Botany* 71: 67–75.
- REBELO, A.G. 1995. Renosterveld: conservation and research. In A.B. Low & F.E. Jones, *The sustainable use and management of renosterveld remnants in the Cape Floristic Region (Proceedings of a Symposium)*: 32–42. FCC Report 1995/4. Flora Conservation Committee, Botanical Society of South Africa, Kirstenbosch, Cape Town.
- REYERS, B., FAIRBANKS, D.H.K., VAN JAARSVELD, A.S. & THOMPSON, M.W. 2001. South African vegetation priority conservation areas—a coarse filter approach. *Diversity & Distributions* 7: 79–89.
- ROMESBURG, H.C. 1984. *Cluster analysis for researchers*. Lifetime Learning Publications, Belmont, California.
- ROUGET, M., RICHARDSON, D.M., COWLING, R.M., LLOYD, J.W. & LOMBARD, A.T. 2003. Current patterns of habitat

- transformation and future threats to biodiversity in terrestrial ecosystems of the Cape Floristic Region, South Africa. *Biological Conservation* 112: 63–85.
- SAVORY, J. 1986. *The effects of overgrazing on the structural-functional composition of West Coast Renosterveld*. Unpublished third year project, Botany Department, University of Cape Town.
- SCHULZE, R.E. 1997. *South African atlas of agrohydrology and climatology*. Water Research Commission, Pretoria, Report TT82/96.
- TANSLEY, S. 1982. *Koppie Conservation Project*. Unpublished report for the South African Nature Foundation.
- THISLTON-DYER, W.T. (ed.). 1896. *Flora capensis* 6. Reeve, London.
- THISLTON-DYER, W.T. (ed.). 1897. *Flora capensis* 7. Reeve, London.
- THISLTON-DYER, W.T. (ed.). 1904. *Flora capensis* 4,2. Reeve, London.
- THISLTON-DYER, W.T. (ed.). 1909. *Flora capensis* 4,1. Reeve, London.
- THISLTON-DYER, W.T. (ed.). 1912. *Flora capensis* 5,1. Reeve, London.
- THISLTON-DYER, W.T. (ed.). 1913. *Flora capensis* 5,3. Reeve, London.
- THISLTON-DYER, W.T. (ed.). 1925. *Flora capensis* 5,2. Reeve, London.
- WOOD, J. & LOW, A.B. 1993. *Environmental survey and management guidelines for the Tygerberg and environs. Part 1*. Unpublished report, National Botanical Institute, Cape Town.
- VON HASE, A., ROUGET, M., MAZE, K. & HELME, N. 2003. *A fine-scale conservation plan for Cape lowlands renosterveld: technical report (main report)*. Report No. CCU 2/03, Cape Conservation Unit, Botanical Society of South Africa.