Open Access

A Computerized Method for Identifying Dispersal Corridors, Using West-Coast Renosterveld as an Example

I.P. Newton*,# and R.S. Knight

Department of Biodiversity and Conservation Biology, University of the Western Cape, Private Bag X17, Bellville 7530, South Africa

Abstract: In this letter we look at a computerized method of identifying pathways based upon a cost-analysis method. Using this method complicated or large-area land-cover patterns can be assessed. We use the example of West-Coast Renosterveld, a vegetation type that has been highly transformed by agriculture.

Keywords: Dispersal corridors, fragmented habitat, west-coast renosterveld, computer method.

INTRODUCTION

Over the past 6 decades, the human population has increased from about 2521 billion in 1950 to about 6707 billion in 2008 [1]. The demand for food and living space has likewise increased. Urbanisation has similarly resulted in cities and suburbs expanding at, sometimes, phenomenal rates. Natural and pseudo-natural areas are rapidly disappearing as formal, and in developing countries informal, dwellings are erected. Those natural areas remaining are often small and isolated from each other by a landscape that is hostile to all but a few species that have benefited by urbanisation or agriculture.

Added to this is the realisation that, as the climate of the earth changes, species which, under past climate change regimes were able to move to more suitable niches, are now imprisoned. Of course, changes in the macro-climate have always led to extinctions, and to the evolution, or adaptation, of other species to exploit the vacated niche [*e.g.* 2]. However, with the current excessive level of fragmentation, abnormally high levels of extinction may be expected with future changes in the climate, due to the inability of those species with insufficient mobility to "migrate" across transformed landscapes to other suitable areas. Even without climate change, genetic isolation, competition from aliens and the input of toxins and fertilisers into the remaining fragments are likely to send many species into oblivion.

There has been a great deal of discussion as to the usefulness or otherwise of dispersal corridors, the cost of their upkeep, the high perimeter to area ratios etc. [*e.g.* 3], and it is not our intention to enlarge on this. Notably lacking are methods for identifying potential dispersal corridors across the landscape. That this is difficult to do is not disputed, as every species perceives the landscape differently, and hence there is no such thing as a "universal corridor". However, this should not prevent us from trying to identify least-distance and "most environmentally friendly" networks. Over small areas with a few (large) natural fragments, this can be done subjectively, by human observation. Where the area is extensive and the fragments are small, numerous and widely scattered, the exercise becomes more difficult. In addition to the difficulty of identifying general patterns by "eyeballing" a map, as the area being examined gets larger, the smaller fragments become lost in the background and are thus excluded from the analysis.

In this paper we examine the use of a "cost-analysis" system, as used by civil engineers, to identify potential dispersal routes, using West-Coast Renosterveld (WCR) plant species, and their pollinators as our example. WCR has recently been divided into a number of sub-units [4], but for conservation planning purposes it is currently considered a single entity [5].

WCR is one of the vegetation types making up the Fynbos Biome, or Cape Floral Kingdom, one of the richest in terms of species diversity in the world [6]. Much of this Biome is situated upon leached, sandy soils [7], that have little conventional agricultural value. Coastal Renosterveld (of which the West-Coast type is one) occurs where the soils have a substantial clay or loam content with nutrient levels that are suitable (with the addition of fertilizers) for growing wheat and vines [8]. This has led to WCR (Fig. **1**) becoming (arguably) the most transformed landscape within South Africa [9-11]. There have been a number of vegetation mapping exercises in this area over the past sixty years, each defining different original extents for WCR. This makes determining the amount remaining difficult to estimate, but it seems certain that less than 10% remains, the two latest estimates being 5% [5] and 9.4% [12].

The remaining fragments are mostly small (average = 39.6ha; median = 8.6ha; n = 1889 of greater than 3ha), and are scattered across 7974km^2 [13] of the landscape, mainly on hillsides and on rocky soils. The average distance separating the larger, ecologically viable fragments (>25 hectares) is 5.2 ± 4.7 km (median = 4.0 km; range = 1.2 to 51.3 km; n = 202). Our estimate of 25 ha as a minimum

---

*Address correspondence to this author at the Department of Biodiversity and Conservation Biology, University of the Western Cape, Private Bag X17, Bellville 7530, South Africa; Tel: +27 21 650 3819; Fax: +27 21 650 2352; E-mail: ian.newton@uct.ac.za

#Present address: Archaeology Department, University of Cape Town, Private Bag, Rondebosch 7700, South Africa

Least-cost pathways were mapped between the 202 chosen fragments and each of eight boundary lines (Fig. **4**) using the "PATHWAY" module. The pixel with the lowest value on the end line becomes the end point. The eight adjoining pixels are then compared and the pixel with the lowest value becomes the next point. This is continued until the line reaches the source pixel [15].

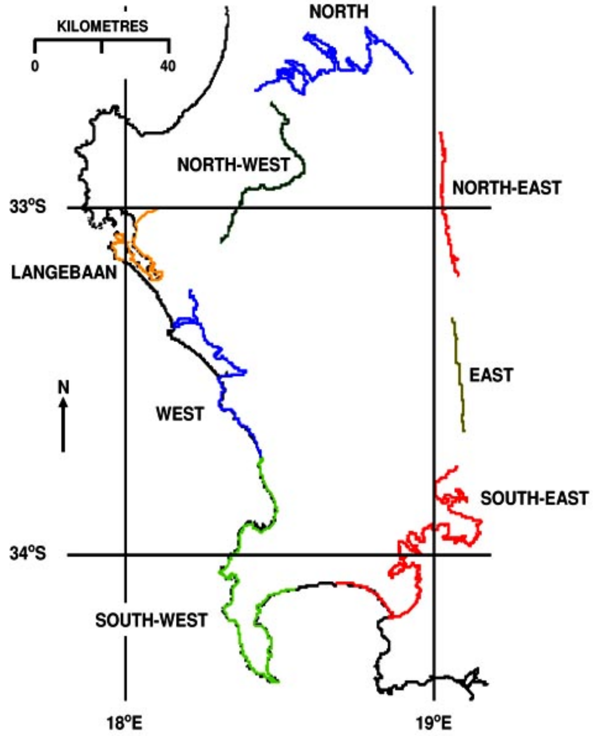

Fig. (4). The eight end-points used for developing the pathways.

The eight pathways produced from each of the cost images (1616 pathways in total) were combined to produce a corridor map. Each corridor section was assigned a value equivalent to the number of paths making up that section of the corridor. A "section" is defined as the line occurring between intersections. Once this had been done, the points where these corridor lines reached the boundary lines (84 points in total) were treated as points of origin, and the whole process repeated, except that pathways were only constructed to the seven boundary lines that were not abutting the point of origin. These cross- Renosterveld "corridor" lines were added to the corridor lines from the fragment source images.

RESULTS

Due to minor calculation differences inherent in an image as large as the one used (7 354 900 pixels), combining the pathway images often led to several corridor lines running parallel to each other through the larger fragments. These lines were combined into a single line to enhance legibility and were given a weight equivalent to the sum of the lines. The important factor to note is that the corridors preferentially exist around the perimeter of the Renosterveld region, rather than crossing it (Fig. **5**). Although the frictional values used in this study did not identify any direct connections between the Peninsula fragments and those of the Tygerberg or Blouberg fragments, the finer-scale local study of [21] identified a coastal corridor between Groote Schuur and Blouberg.

Fig. (5). Dispersal corridors identified by the cost analysis of West-Coast Renosterveld.

DISCUSSION

This technique was used by [21] to determine natural vegetation corridors occurring within the Greater Cape Town area. In that study the authors used a system whereby nodes (points where corridor lines overlap) were created, and a weight, based upon the number of paths intersecting that node was assigned to that node. Nodes with high scores indicated locations of high ecological importance which need to be conserved. Due to the large number of intersections occurring in this study, a system of weighting the corridor lines themselves was used instead.

Our aim here is not to provide a definitive description of dispersal pathways for all Renosterveld species. It is rather to indicate how this method can be used to identify general patterns of connectivity within a (large) complex and ecologically hostile landscape, and to help identify areas that are likely to be isolated from the general population. It could be used to provide overviews of, for example, patterns of connectivity in developing countries where ground data are limited and difficult to access. Our study area only covers an extent of 184 km (N–S) by 78 km (E–W). One only has to examine Fig. (**1**) to realize that manually trying to identify potential dispersal routes using all the fragments would be difficult, if not impossible. Even when the image was blown up to cover two A0 sheets (as was done for ground-truthing purposes), the smaller fragments were often lost in the background. The study of [5] identified fragments down to single pixel size. These would be impossible to see, and one could easily imagine 50 ha or larger fragments becoming lost in the background of country-wide analyses.

An advantage of this method is that same land-cover types are treated equally across the whole area (unless the friction image specifies regional differences). Manual analyses result in sub-conscious differences in the weighting of the same land-cover types, even when there is no ecological reason for doing so. Of course, one might argue that, for example, a single wheat field 100 m wide has a smaller barrier effect than many adjacent fields stretching across several kilometers. Nevertheless, the consistent frictional weightings of each type of land-cover pixel should ameliorate this effect.

Compare our corridor analysis of WCR with that produced by [5]. They identified a “corridor” (their “coastal gradient”), which approximates the southern-most (A) east-west pathway shown in Fig. (**5**). While this pathway is of importance, particularly for linking the natural vegetation on the Cape Peninsula with other natural areas, the more northerly (B) of the two thick corridor lines is probably more important for Renosterveld species, and also supplies an alternative to the southern-most corridor, which is increasingly coming under threat from urban expansion. A further disadvantage of the southern-most corridor (A) is that more of it is situated on Quaternary sands, which are often incompatible with Renosterveld plant species, (and in some cases, their pollinators [22]) than is the case with the northern corridor. In fact, the thinner corridor line (C) has the most likelihood of providing an east-west dispersal route for those species with a low range of edaphic tolerance.

Although the procedure we used indicates the “cost” of traveling across the different land-cover types, we did not take into account other factors that act independently of land-cover. Such factors include wind, for wind-dispersed propagules and slope for the more terrestrially bound vectors. Our study area receives predominantly north-westerly winds in winter, and south-easterly winds in summer. Topographically it is predominantly flat. If individual species were being examined, these factors could have been incorporated into the analysis.

A number of objections may be raised as to the validity of this technique, the most important of which is the frictional values ascribed to the land cover types. Over relatively small areas, such as that described by [21], detailed information on environmental conditions may be collected and a more definite goal may be ascribed, thus making frictional allocations easier. With larger areas, such as the one described here, this is more difficult. For example, although WCR is confined to the more nutrient rich soil types [7], there are actually several types of substrate, each with its own characteristics e.g. shales, granites, loamy sand [23-25]. In addition, despite the relatively small area covered by this vegetation type, there is a steep increase in rainfall as one moves from the north-west to the south east (<300mm to >1200mm [26]). An analysis of the distribution of the rare and endangered plant species [27] suggests that within this area, many of the endemics have microhabitat requirements that do not show up, even at the 1:50 000 scale. In addition to these apparent micro-habitat requirements, analyses of the dispersal distances of many Fynbos (including Renosterveld) endemics, has shown that their seed dispersal distances are often very small (<10m) [28], and often restricted to the period immediately after a burn [29], which may only occur at 10 to 25 or more year intervals. It has even been suggested [14] that a short dispersal distance benefits the species, as a dense community of insect pollinated species will attract pollinators more effectively than widely dispersed individuals. For these species, dispersal corridors are of little use, except for pollinator dispersal and the possible mixing of genetic material from different populations. We acknowledge that, given a specific task, one would incorporate as much information as possible into the frictional allocation, and possibly experiment with different values. With the information and resources available to us, we chose values that we considered reasonably reflected an average potential for dispersal, relative to “pure” Renosterveld. Based on our local knowledge, we believe that the general pathway pattern produced, does reasonably reflect the dispersal potential within the area examined.

A current disadvantage is the extended use of computer time required to complete each analysis. Although the cost analyses themselves can be left to run sequentially in macro mode, combining the resulting corridors and assigning a total to each line section is a lengthy process that currently requires human intervention, although this may not be necessary during preliminary analyses. Computer time could be reduced to a certain extent by using the alternative “Costpush” option of the “COST” module. This option does not allow for the presence of a total barrier (such as for the ocean or areas outside the study area), although such areas could be given very high values. Restricting the frictional values to “byte” sized values (0 to 255) would further help speed up the processing. Increases in the processing speed of personal computers will also help speed analyses, and there is also the potential for the development of a dedicated program (along the lines of C-Plan for reserve analyses).

CONCLUSION

We have shown in this exercise that by making use of the tools used by civil engineers it is possible to obtain a relatively objective view of fragmented landscapes, as humans perceive them to be, in terms of eco-friendliness. We acknowledge that this method remains subjective to the extent that the costs assigned to the different land-cover types are determined by humans. Similarly the same land-cover type can vary enormously in terms of its ecological compatibility for different organisms. The Landsat imagery used is provided at a nadir resolution of 28.5m, which is too coarse to identify the quality of road verges, field verges, strips of natural vegetation across fields etc. These are also problems that beset those who use a subjective “eye-balling” procedure. Nevertheless, the method described here can take into account complicated mosaics of land cover over large areas.

ACKNOWLEDGEMENTS

This material was based upon work supported by the National Research Foundation of South Africa under Grant number 2053674 awarded to Professor Suzanne J Milton. This work was carried out as part of the requirements of a Ph.D. thesis at the University of the Western Cape by IPN, who acknowledges the receipt of an NRF bursary. We thank three anonymous referees for their comments.

REFERENCES

[1] http://en.wikipedia.org/wiki/World_population. February, 2010

[2] Linder HP, Meadows ME, Cowling RM. In: Cowling RM, Ed. The ecology of Fynbos: Nutrients, fire and diversity. Cape Town, Oxford University Press 1992; pp. 113-34.

[3] Beier P, Noss RF. Do habitat corridors provide connectivity? Conserv Biol 1998; 12(6): 1241-52.

[4] Mucina L, Rutherford MC, Eds. Vegetation Map of South Africa, Lesotho and Swaziland: shapefiles of basic mapping units. Beta version 3.0. Cape Town: National Botanical Institute 2004.

[5] Von Hase A, Rouget M, Maze K, Helme N. 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 2003.

[6] Bond P, Goldblatt P. Plants of the Cape Flora – a descriptive catalogue. J S Afr Bot 1984; Supplement 13 : 1-455.

[7] Boucher C, Moll EJ. In: di Castri F, Goodall DW, Specht RL, Eds. Ecosystems of the World 11: Mediterranean-type shrublands. Amsterdam, Elsevier 1981; pp. 233-48.

[8] Talbot WJ. Swartland and Sandveld. Cape Town: Oxford University Press 1947.

[9] McDowell C. Factors affecting the conservation of Renosterveld by private landowners. University of Cape Town: Unpublished Ph.D. thesis 1988.

[10] Reyers B, Fairbanks DHK, van Jaarsveld AS, Thompson MW. South African vegetation priority conservation areas – a coarse filter approach. Divers Distrib 2001; 7: 79-89.

[11] Rouget M, Richardson DM, Cowling RM, Lloyd JW, Lombard AT. Current patterns of habitat transformation and future threats to biodiversity in terrestrial ecosystems of the Cape Floristic Region, South Africa. Biol Conserv 2003; 112: 63-85.

[12] Newton IP, Knight RS. The use of Landsat imagery for the identification of the remaining West Coast Renosterveld fragments, Western Cape Province, South Africa. S Afr J Bot 2005; 71: 67-75.

[13] Newton IP. Recent transformations in West-Coast Renosterveld: Patterns, processes and ecological significance. University of the Western Cape: Unpublished Ph.D thesis 2008.

[14] Donaldson J, Nanni I, Zachariades C, Kemper J. Effects of habitat fragmentation on pollinator diversity and plant reproductive success in Renosterveld shrublands of South Africa. Conserv Biol 2002; 16(5): 1267-76.

[15] Eastman JR. Idrisi32: Guide to GIS and image processing. Worcester, Ma: Clark University 1999.

[16] Kemper J. The effects of fragmentation of South Coast Renosterveld on vegetation patterns and processes. University of Cape Town: Unpublished M.Sc. thesis 1997.

[17] Heydenrych BJ, Littlewort PE. 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 South Africa 1995.

[18] Boucher C. Floristic and structural features of the coastal foreland vegetation south of the Berg River, western Cape Province, South Africa. In: Moll E, Ed. Proceedings of a Symposium on the Coastal Lowlands of the western Cape; Mar 19-20 1981. University of the Western Cape 1981; pp. 21-25.

[19] Low AB, Rebelo AG. Vegetation of South Africa, Lesotho and Swaziland. Pretoria: Department of Environmental Affairs and Tourism 1996.

[20] Cowling RM, Heijnis CE. The identification of Broad Habitat Units as biodiversity entities for systematic conservation planning in the Cape Floristic Region. S Afr J Bot 2001; 67: 15-38.

[21] Anonymous. Identification of a biodiversity conservation network for the city of Cape Town; Executive summary. City of Cape Town: Unpublished report for the Environmental Management Department, Cape Town 2002.

[22] Pauw A, Bond WJ, Hawkins JA. Reconstruction of a historical pollination landscape reveals the disruption of mutualisms in small conservation areas. In: Arianoutsou M, Papanastasis V, Eds. Proceedings 10th MEDECOS Conference, April 25 – May 1, 2004, Rhodes, Greece. 2004. CD file: "104.pdf”

[23] Anonymous. 3218 Clanwilliam: 1:250 000 Geological Series. Pretoria: Government Printer 1973.

[24] Anonymous. 3318 Cape Town: 1:250 000 Geological Series. Pretoria : Government Printer 1990.

[25] Anonymous. 3319 Worcester: 1:250 000 Geological Series. Pretoria : Council for Geoscience 1997.

[26] Schulze RE. South African atlas of agrohydrology and climatology. Pretoria: Water Research Commission, Report TT82/96 1997.

[27] Newton IP, Knight RS. How homogeneous is West Coast Renosterveld? Implications for conservation. Bothalia 40(2), in press.

[28] Cowling RM, Holmes PM, Rebelo AG. In: Cowling RM, Ed. The ecology of Fynbos: Nutrients, fire and diversity. Cape Town, Oxford University Press 1992; pp. 62-112.

[29] Le Maitre DC, Midgley JJ. In: Cowling RM, Ed. The ecology of Fynbos: Nutrients, fire and diversity. Cape Town, Oxford University Press 1992; pp. 135-74.

Received: October 15, 2009 Revised: March 03, 2010 Accepted: May 21, 2010