Long-term vegetation monitoring – a 33 year record from Table Mountain

Paul Ivor Emms

Supervised by Prof. Eugene Moll

UNIVERSITY *of the* WESTERN CAPE

THESIS

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Paul Ivor Emms

KEY WORDS

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ABSTRACT

Nearly 40 years ago McLachlan and Moll highlighted the need for a well-defined path system on the Western Table of Table Mountain in the immediate vicinity of the Upper Cable Station (UCS). At that time the numbers of people using the cableway was heavily impacting the vegetation on the Western Table, particularly in the vicinity of the UCS. This prompted a study by Coley (1977) to assess the long-term impacts of trampling in this area.

In order to monitor changes in the vegetation through time Coley set up 12 permanently marked plots (each ~4x4 m), arranged at increasing distances from the UCS. Plot positions were carefully selected so that the effects of trampling on the vegetation could be measured at various points (distance being a surrogate for trampling intensity). Field observations in 1977 revealed that Mountain Fynbos vegetation was heavily impacted by cableway tourists. Furthermore the vegetation was most damaged closest to the UCS, with a sharp decrease in damage with increasing distance from the station.

In order to monitor the vegetation change Coley used aerial photographs of permanently marked plots, so that visual comparisons of species cover, condition and composition could be made over time. The vegetation was then assessed in terms of percentage cover, and percentage damaged for each plot. My study marks the fifth time data were collected since Coley (1977) and the results show that there has been a marked improvement in vegetation quality since the construction of well-defined paths and a concerted effort by managers to ensure tourists do not leave the paths; which has greatly reduced trampling since the 1997 upgrade. The implications of this study provided evidence of the importance of restricting

tourist traffic in areas that are regularly visited and, therefore, highly impacted. It also shows that denuded fynbos is resilient and does recover over time, provided that the substrate is not eroded too heavily by trampling. Finally, I present several management recommendations, of which the most controversial, albeit important, is for a rotational block burn programme on the Western Table; since fire is a keystone ecological process that has been absent of the Western Table for at least 80 to 90 years.

DECLARATION

I declare that the *Long term vegetation monitoring – a 33-year record from Table Mountain* is my own work, that it has not been submitted to any degree or examination in any other university, and that all the sources I have used or quoted have been indicated and acknowledged as complete reference.

Paul Ivor Emms November 2013

Signed………………………………

Note to the examiner: This thesis follows the South African Journal of Botany ‘Guide for Authors’ and University of the Western Cape ‘Thesis Guide’ (Planning and writing a thesis and submitting it for examination). The text has been justified for presentation purposes.

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CHAPTER 1: INTRODUCTION AND BACKGROUND

1.1. Human impacts on Table Mountain

The notion of "A Mountain in a City" (Moll et al. 1978) could not be better exemplified than by Table Mountain, situated within the heart of Cape Town, South Africa. The mountain massif has attracted visitors since the arrival of the first European settlers in 1652 (Marloth 1908; Adamson 1953 in Moll et al*,* 1978). An important consequence of this is the degree of impact imposed by human trampling on the vegetation. Whilst the Western Table has been subjected to increasing numbers of tourists over time, it was not until 1926 (TMAC, 2011) – when construction of the cableway by the Table Mountain Aerial Cableway Company (TMACC) was initiated - that the area began to experience significant impacts as a result of increased visitation. The cableway was opened on 4 October 1929 (TMACC 2011), heralding a wave of tourist pressure increasing as the years went by because of various upgrades to the cableway. Since its opening the cableway has transported over 21 million people to the top of the mountain (TMACC 2012).

Tourist numbers have not been evenly spread over this time. The first cable car was significantly smaller than the current model and had a capacity for carrying only 19 passengers per trip (TMACC 2011). The second car in operation was in 1958 and carried 23 passengers, followed by the introduction of two 28 passenger capacity cars in 1974 (TMACC 2011). The most significant and major upgrade and revamping of cableway infrastructure was completed in 1997. The 1997 car, which is still in use, has a 65 passenger capacity. After the 1974 upgrade tourist numbers started to rise steadily, and soon reached the 5 million mark by 1980, and then rose again following the increased cable car capacity in 1997 (Figure 1).

Concern over the deterioration of the mountain's biotic communities was probably not apparent in the early years but later notes by Adamson (1935 in Moll, et al. 1978) and Luckhoff (1951 in MCSA 1974), along with huge public interest, were instrumental in the proclamation of Table Mountain as a National Monument in 1951 (Luckhoff, 1951 in Moll, et al. 1978). Little in the way of conservation awareness programmes transpired in the ensuing years until a report in 1974 by the Mountain Club of South Africa (MCSA) highlighted the major threats facing the Mountain (Moll et al. 1978). Concerns then focused on problems such as invasive alien vegetation, "*erosion, fires, vandalism and litter*" – and at the heart of this being the concern of increased human population pressure (MCSA 1974).

Paths on the Mountain were noted as areas of special concern in light of the erosive nature along frequently used trails (MCSA 1974). As a rule, rather than exception, paths were formed due to trampling as a result of a lack of mountain-path infrastructure (MCSA 1974). The area in the vicinity of the Upper Cable Station (UCS) was no exception. The report by the MCSA gave recommendations for the need to construct paths where necessary and *"barricades and fences",* so that extensive erosion to areas such as steep ravines and slopes could be mitigated. Apart from the impact of humans, extensive damage was also being caused by the alien Himalayan Tahr (*Hemitragus jemlaccus*) (MSCA 1974). Although now apparently exterminated from the Mountain, these animals frequented the steeper slopes and cliff faces and it should be noted that their impact was not only that of grazing and browsing, but also from trampling (MCSA 1974). In terms of ecological impacts it would seem that the major difference between human versus Tahr trampling was more a case of what was more noticeable. Impacts by humans occurred where humans frequented (and with more intensity) whilst impacts by the

Tahr were mostly unseen to the average mountain visitor who did not frequent the extreme cliff habitats of the Tahr.

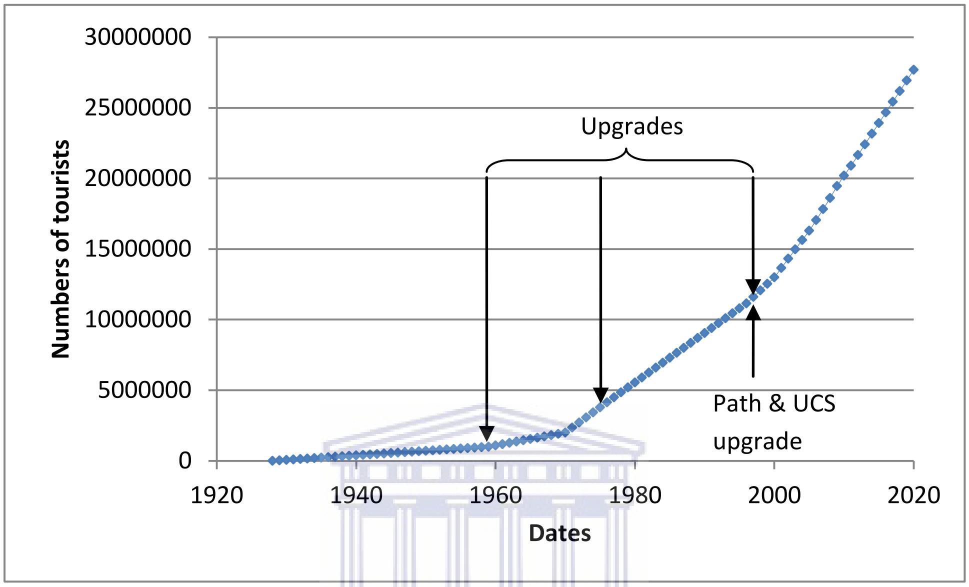

Figure 1. Cumulative cableway tourist numbers between 1929 and 2010 within a 100 year window (TMACC 2012).

1.2. The Upper Cable Station

Of particular importance to the conservation and management planning of Table Mountain, and with specific reference to the area surrounding the Upper Cable Station (UCS) on the Western Table, were two reports produced by members of the Department of Botany at the University of Cape Town (UCT). The first, titled The Ecological Status of Table Mountain (Moll & Campbell 1976), highlighted the following: *"A system whereby changes in the plant communities can be accurately monitored needs to be devised and implemented. The effect of* *influences such as fire, grazing and trampling cannot be accurately measured unless such monitoring is done".* They stated further: *"The sighting of the Cable-way station has led to very serious degradation in parts of the Upper Plateau. The species* Thamnochortus nutans *(Restionaceae) is threatened"* (Laidler et a*.,* 1978 – study completed in 1976).

The second report titled "A Path and Recreation Report of Table Mountain" (McLachlan & Moll 1977) was produced that paralleled the key study by Coley (1977 Unpublished). The latter study was initiated primarily as a result of Moll and Campbell's preliminary findings (Coley 1977 Unpublished). The report by McLachlan and Moll (1977) addressed the major causes of path erosion on Table Mountain, namely heavy use, path design, the substrate beneath the path and path construction; among other factors. The report once again drew attention to the Western Table and impacts imposed on the vegetation in the immediate vicinity of the UCS. Included were concerns and recommendations aligned to mitigate these impacts and improve the site for both visitor and the environment: *"It is predicted that with increasing numbers of people, there will be a rapid increase in the degree of deterioration and/or change of species composition. This encroachment on the vegetation is greatest near the upper cableway station, and decreases with distance away from it. This situation could be much improved if a proper network of paths was established, to channel the people."*

My study was also influenced by Laidler et al. (1978) who noted the following: *"The location of the Upper Cableway Station on the Western Table is responsible for a large volume of tourist traffic on the Front Table. This has resulted in extensive degradation of the vegetation especially* *within close proximity of the station and restaurant. Further away there is also much damage and despoilment along the edges of the foot-paths particularly along the front face."*

It is, therefore strongly recommended that well landscaped paths be constructed in areas where degradation is visible. This would, in fact, entail the planning of the path network on the Western Table, so that a few major routes are hardened. Visitor access should be restricted to these paths to prevent further extensive degradation of the plant communities and allow their recovery."

Coley's (1977) study was significant since it was the first effort to monitor the effects of trampling and ascribe quantitative evidence for these impacts. Of key importance was the need to control the tourist traffic at the site. Moll and McLachlan (1980) consolidated these efforts with a plan for a proposed path network for the area. In 1997 the first formal path system was at last constructed when the path system was upgraded, repaved and improved substantially. Paths were constructed using a combination of cement, stone chip and terracotta dye for a more natural effect and barriers were erected to restrict visitors to the paths (Figure 2).

Figure 2. The concrete path system implemented after the 1997 major upgrade.

Coley's report also mentioned that concern for the status of plant communities within the study area was also raised in an interim report on the rare and endangered plant species of Table Mountain, calling for a detailed assessment (The Rare and Endangered Plant Species Unit 1976 in Coley 1977 Unpublished). Coley went on to note that it was of paramount importance to implement an efficient monitoring system as a means to formulating a strategic management programme for Table Mountain. A long-term study using permanently marked vegetation plots to monitor changes in vegetation impacted by human trampling was thus undertaken. Coley's 1977 findings showed that cableway tourists heavily impacted the vegetation, and that vegetation was most damaged closest to the UCS. Following this initial study and the setting up of permanent plots, reassessments were conducted by botany students from UCT, including Aubin (1985 Unpublished), van Coller (1988 Unpublished), Kerbelker (1988 Unpublished) and from the University of the Western Cape by Emms (2005).

Then in 1982 the City of Cape Town's (CoCT) City Engineers Department, with the backing of several key authorities, namely the Interim Management Committee for Table Mountain and the South Peninsula Chain, Table Mountain Preservation Board, Table Mountain Nature Reserve Advisory Board, National Monuments Council and Cape Department of Nature and Environment Conservation, produced a Master Plan for the Western Table (CoCT 1982). One of the key recommendations was to construct a new path system on the Western Table. Among the recommendations were specifications for path constructions using mountain stone chip embedded in mortar, with the use of larger natural rock fragments. Path specifications were made on the basis of human traffic intensity. Paths in the intensive use area were planned to be wide enough for four pedestrians abreast (3.2 m wide), along the main path for three persons abreast, and along the secondary and less frequented areas (2.4 m wide); with slopes not exceeding 1:12 to facilitate use by the physically disabled persons. Use of barriers to restrict tourists to the paths system was also advocated. Plans were also included to widen some of the viewing platforms and to lift paths in wet areas so that water movement would not be altered. Removal of rubble was also mentioned in addition to a vegetation rehabilitation plan.

1.3. Scope of the study

The objectives of the study are to compare the vegetation data collected from Coley's 12 permanently marked plots laid out on the top of Table Mountain in 1977, and subsequently re-measured at varying intervals until 2010. This has provided data that requires analysis to identify what changes have taken place to the vegetation over a 33 year time period; during which time the whole path system on the Mountain was radically up-graded in 1997.

Table Mountain is one of the most visited sites in South Africa and the trampling effect of the tourists has had a deleterious impact on the fragile fynbos vegetation, which has supposedly been mitigated but the establishment of permanently constructed pathways (1997). With the recent decrease in disturbance it is appears that parts of the upper plateau may have to be managed using fire to maintain the unique biodiversity of this iconic fynbos place.

This study marks the fifth time period that data has been collected from Coley's plots (Figure 4) and is intended to amalgamate, analyse and present the major changes that have occurred over the 33 year period. The study is intended to show the changes that have occurred to the vegetation in relation to visitor impacts, specifically trampling, and to provide recommendations for better management of the area based on the findings. The hypotheses that are being tested are as follows:

1. That there has been a marked improvement in the vegetation quality since the implementation of a proper path system in 1997, since the paths have ensured that tourists do not stray from the paths, and therefore have no, to very little, impact on the vegetation; and
2. That although the vegetation has recovered, the long fire period interval and lack of disturbance is leading to a decline in species diversity, implying that fire is needed to maintain the species diversity.

1.4. Description of the study area: physical environment and vegetation

The plateau of the Western Table is a relatively small area in comparison to the rest of Table Mountain (Figures 3 & 4) and the Cape Peninsula mountain chain, being approximately 690 m long and varying between 90 m to 240 m wide (CoCT 1982). A geological fault, Platteklip Gorge, divides the Western Table from the Eastern Table, the larger portion of the plateau, which extends to the highest point at Maclear’s Beacon (1 086 m above sea level) (Laidler et al. 1978). The area leased by the TMACC was estimated at 9 000 m^2 in 1982 (CoCT 1982).

The vegetation on the Western Table comprises a variety of plant communities, which are influenced by the physical environment. The abiotic environment is relatively hostile in terms of the topography, substrate and climatic conditions. Most pertinent is the substrate and micro-topography – key attributes influencing the distribution of the plant communities. Shallow soils occur between exposed bedrock, which forms pools when sufficient moisture is available. Laidler et al. (1978) and Glyphis et al. (1978) noted that within some of the plant communities on the Western Table the exposed rock can vary between 50% and 75% cover. Where there is soil the depth varies between 50 – 150 mm and is regarded as the main reason for the low structural height of the vegetation (CoCT 1982). Pools are more common towards the Maclear’s Beacon side of the Western Table and most abundant on the Eastern Table. Laidler et al., (1978) identified three environmental factors driving plant communities on the Western Table, namely (1) soil depth, (2) site drainage and available moisture and (3) rock cover.

Where the pools occur vegetation is usually sparse or non-existent since these are often coupled to exposed rock surfaces. The high moisture supports moss communities within the

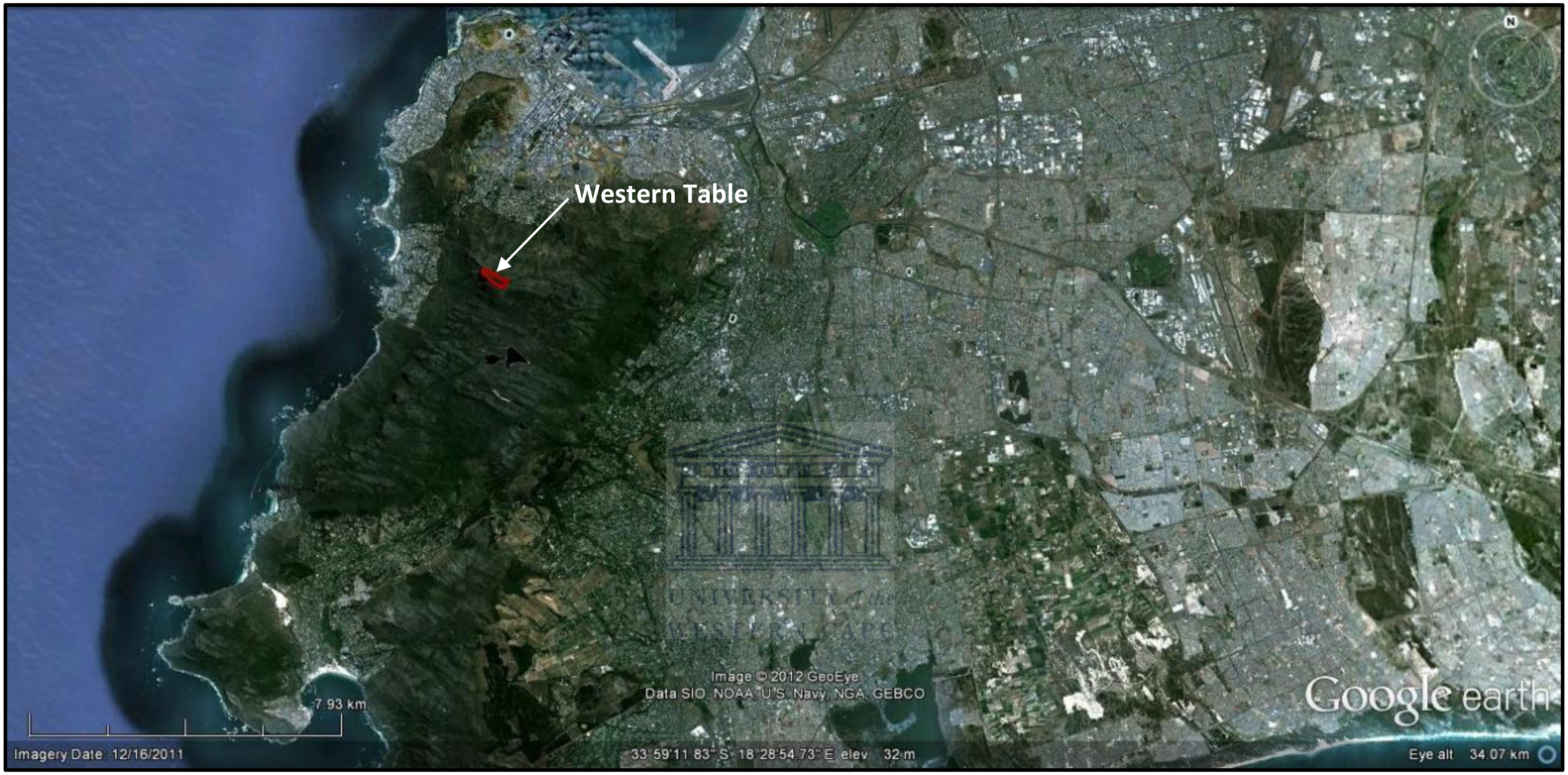

Figure 3. Google Earth ™ aerial image showing the locality of the study area (red outline) on the Western Table of Table Mountain.

Figure 4. Google Earth ™ aerial image showing the approximate position of Coley's permanent vegetation plots (numbered yellow squares) on the Western Table of Table Mountain. The red outline indicates the approximate edge of the plateau. The original informal path scar known locally as 'Eloff Street' is indicated by the orange line and reservoirs scar indicated by the blue outline.

shallowest soils. These communities may also contain seedlings of various species; however, the shallow substrate does not allow for their survival and they could thus be considered seedling communities in their own right.

Precipitation on the Western Table occurs primarily in the form of rain and fog (Nagel 1956), with occasional snow falls limited to the upper reaches. Notably, the high altitude leads to significantly different climatic conditions when compared to the lower reaches of the mountain. Summer fog offers relief to the flora, which would otherwise be compromised under the harsh windy conditions and shallow soils. Prevailing winds are the fog-bearing south-easter (summer) and rain-bearing north-wester (winter). The average velocity of south-east winds is 6.7 m per second whereas the north-west winds are very similar in strength at 6.9 m per second (CoCT 1982). The fog precipitation provides a major proportion of moisture, which may account for over 80 % of the total precipitation on the Western Table (Nagel 1956). Marloth (1905) was the first to measure the importance of the role of fog on the vegetation on Table Mountain. Using a series of ingenious but simple experiments he inserted plant stems into rain gauges and measured the moisture runoff from various species. Interestingly the Upper Plateau (Maclear's Beacon) is covered in fog for approximately 31 % of the year (Nagel 1956). Temperatures are between 3˚C to 6˚C cooler on the Plateau of Table Mountain than the lower lying areas on the Peninsula (Nagel 1956). Mean daily temperatures recorded from the UCS are 16˚C and 8˚C for the maximum and minimum respectively (CoCT 1982).

The vegetation of the Western Table is classified as Peninsula Sandstone Fynbos (Mucina, Rutherford & Powrie, 2005) (Figure 5). The vegetation type is endangered (Government Gazette

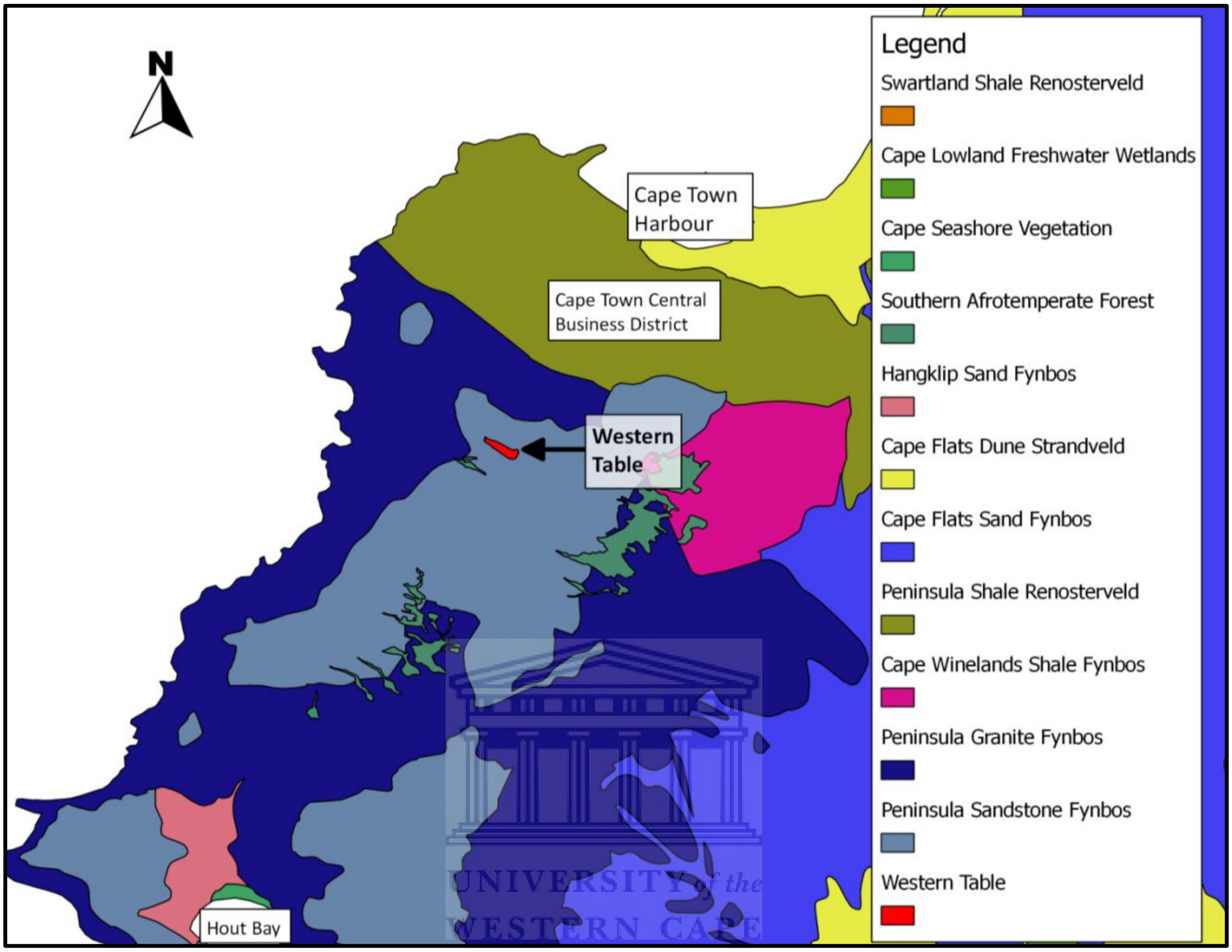

Figure 5. The study area represented on a map portion of *The Vegetation Map of South Africa, Lesotho and Swaziland* (Mucina, Rutherford & Powrie 2005).

2011), since it is confined to the Cape Peninsula, and is broadly described by Rebelo et al. (in Mucina & Rutherford 2006) as *"…a medium dense, tall proteoid shrubland over a dense moderately tall, ericoid-leaved shrubland-mainly proteoid, ericaceous and restioid fynbos, with some asteraceaous fynbos*." The flora of the Cape Peninsula is complex and exhibits an exceptionally high species-richness. Within the confines of only 471 km^2 there are some 2 285 plant species – a phenomenon realized by the very long geological gradients and steep habitat gradients along the Peninsula (Trinder-Smith et al*.* 1996). Consequently plant communities are not homogeneous across this gradient.

From my observations the plant communities occurring in the vicinity of the UCS are distinctly different from those found several hundred metres away (Figures 6 & 7). The obvious differences in the vegetation in the vicinity of the UCS (Plots 1 to 9) (Figure 6) are more varied in structure. The undisturbed areas are well preserved, having ancient individuals of *Cliffortia ruscifolia* (Figure 6), whereas the species is also dominant in the recovered areas away from the previously impacted areas. Of critical importance to the ecological history of the Western Table is the fire history. According to the South African National Parks (SANParks) veld age map, the Western Table has not burnt for at least 80 to 90 years (SANParks 2012). This is highly significant in terms of the effects on species diversity and vegetation composition since fire is a key driving force in fynbos systems (Cowling & Richardson 1995). The implications of the long period without fire are discussed in Chapter 5.

Figure 6. An example of the vegetation occurring close to the Upper Cable Station, in a protected rocky area. The community in this image comprises old individuals of *Cliffortia ruscifolia* along with *Restio perplexus* and *Erica plukenetii*. The stands of *Cliffortia ruscifolia* are thought to be very old since the often broad canopy spread with prickly leaves is a deterrent to tourists.

Figure 7. An example of the plant communities occurring further away from the Upper Cable Station. Note the dominance of restioids.

CHAPTER 2: LITERATURE REVIEW

2.1. Paths, trampling and vegetation

There is very little in the literature relating to impacts of human trampling in mountain fynbos. Internationally, however, there is ample literature on trail management, which gives some mention of the impacts of human trampling. Historically, management of adversely affected vegetation and soils has been based on reactive management intervention; that is, remediation of areas subjected to high intensity recreational use that usually only occurred once the damage was evident (Schofield and others in Burden & Randerson 1972). Depending on the use of any natural or semi-natural area, and the related sensitivity and level of conservation importance of the habitat or a particular species, this level of land 'importance' versus the degree to which the land is allowed to deteriorate can be termed the carrying capacity (Burden & Randerson 1972). When the carrying capacity is exceeded, the desired land state, be it the preservation of a rare plant species or football field, undergoes deterioration (Burden & Randerson 1972). Typically low carrying capacity areas are more sensitive and therefore should receive less traffic, whereas less sensitive sites can withstand higher levels of traffic and may require a higher level of management intervention to maintain the *status quo* (Burden & Randerson 1972).

The direct effects of trampling on plants may induce bruising and crushing, whereas compaction of soil can affect the porosity of soils, leading to long-term impacts (Burden & Randerson 1972). Not surprisingly, it is the most sensitive species that suffer the heaviest losses when subjected to a high trampling intensity (Burden & Randerson 1972); and the more resilient species that survive the longest under continued pressure. Resprouting species, for example, allow species to persist after a wide range of disturbances, with the resilience to resprout usually being related to (1) the species (i.e. week versus strong resprouters) and (2) the intensity of the disturbance (i.e. the higher the disturbance intensity the lower the ability to resprout) (Vesk & Westoby 2004). Sprouting is of particular importance under disturbance patterns that do not allow for the establishment of seedlings (Vesk & Westoby 2004). Likewise pioneer seeding species are resilient since they are capable of re-colonizing trampled areas. Using such indicator species, their relative resistance traits can be used to give insight into the ecological history and present state of recreational areas.

Effects of trampling inevitably influence species composition. Successional changes can also be influenced by the prevailing disturbance regime, and may influence the entry of successional climax species for a long period after the disturbance is alleviated (Noble & Slatyer 1980). Zonation patterns often occur in semi-natural environments, for example, Bates (1935 in Burden & Randerson 1972) observed grass (*Poa pratensis*) in the central or most heavily trampled zones of a study area, and noticed that the species was flanked by *Trifolium repens* and *Lolium perenne*. Although natural areas are more complex in terms of species diversity, soil make-up and micro-topography - in particular in the fynbos ecosystems; indicator species certainly appear in trampled areas such as informal paths. The degree of change in terms of the vegetation cover and indicator species is determined by the recreation pressure. An obviously implication to high numbers of humans frequenting sensitive areas with low management intervention, is deterioration of habitat. An interesting note by Wager (1965 in Burden & Randerson 1972) of semi-natural disturbed areas is that the application of watering reduces the degree of desiccation and death of crushed vegetation and promotes regeneration.

Another interesting note by Boucher (pers. comm. 2012) was made regarding paths made by flower pickers in the now Kogelberg Biosphere Reserve. Flower pickers were active in the 1930's until legislation led to these activities being stopped in the 1940's and 1950's. Paths made by flower pickers were evident on aerial photos taken in 1933 and in the next set of images some 15 to 20 years later. Boucher found these paths during the 1970's whilst conducting fieldwork, since the substrate had been eroded sufficiently to prevent re-establishment of seedlings.

A similar scenario exists at my study site, where old paths, which have been fenced off since 1997, are still evident; most notably the old 'Adderly Street' aka 'Eloff Street' path is still evident as an exposed rocky pathway (Figures 8, 9 & 10). Past and present landscape images taken by Moll (1975) and Emms (2013) from the same point, provide a vivid example of the vegetation changes that have occurred in response to the disturbance regime. The 16-year interval between the paired images in Figures 8 and 9 respectively, show some obvious changes, such as the removal of pine trees (Figure 8) and the old reservoirs (Figure 9). The two reservoirs were removed during the 1997 upgrade. No pines remain today apart from undetected juvenile specimens amongst rocks. In some case the dominant species can be detected; for example, in Figure 8 the dominant species for both time periods are *Erica plukenetii*, *Hymenolepis parviflora* and *Cliffortia ruscifolia.* Obvious changes in Figure 9 are a lack of restioids and high cover of Moss in 2013. It is important to consider that there are two main factors at play here:

1. the tendency for tourists to follow the path of least resistance; and

2. the impact of trampling on vegetation.

A flat, exposed rocky area is more comfortable to traverse than a vegetated path. Thus there would inevitably be a combination of the impacts contributing to the problem - trampling and the tendency to follow the path of least resistance. It is important not to underplay the impacts of trampling as the major contributing factor to long-term vegetation damage – as evidenced by the fact that path 'scars' are present. Lastly, an interesting note by Marion and Leung (2001) indicates that many visitors to recreational areas prefer *"more natural-looking unsurfaced trails, even in developed settings".* The new path system on the Western Table, which had to be surfaced in order to be more user-friendly for tourists and wheel chair access, included natural sandstone chip and dyes mixed in the cement, and successfully achieved a more natural feel (Figure 2).

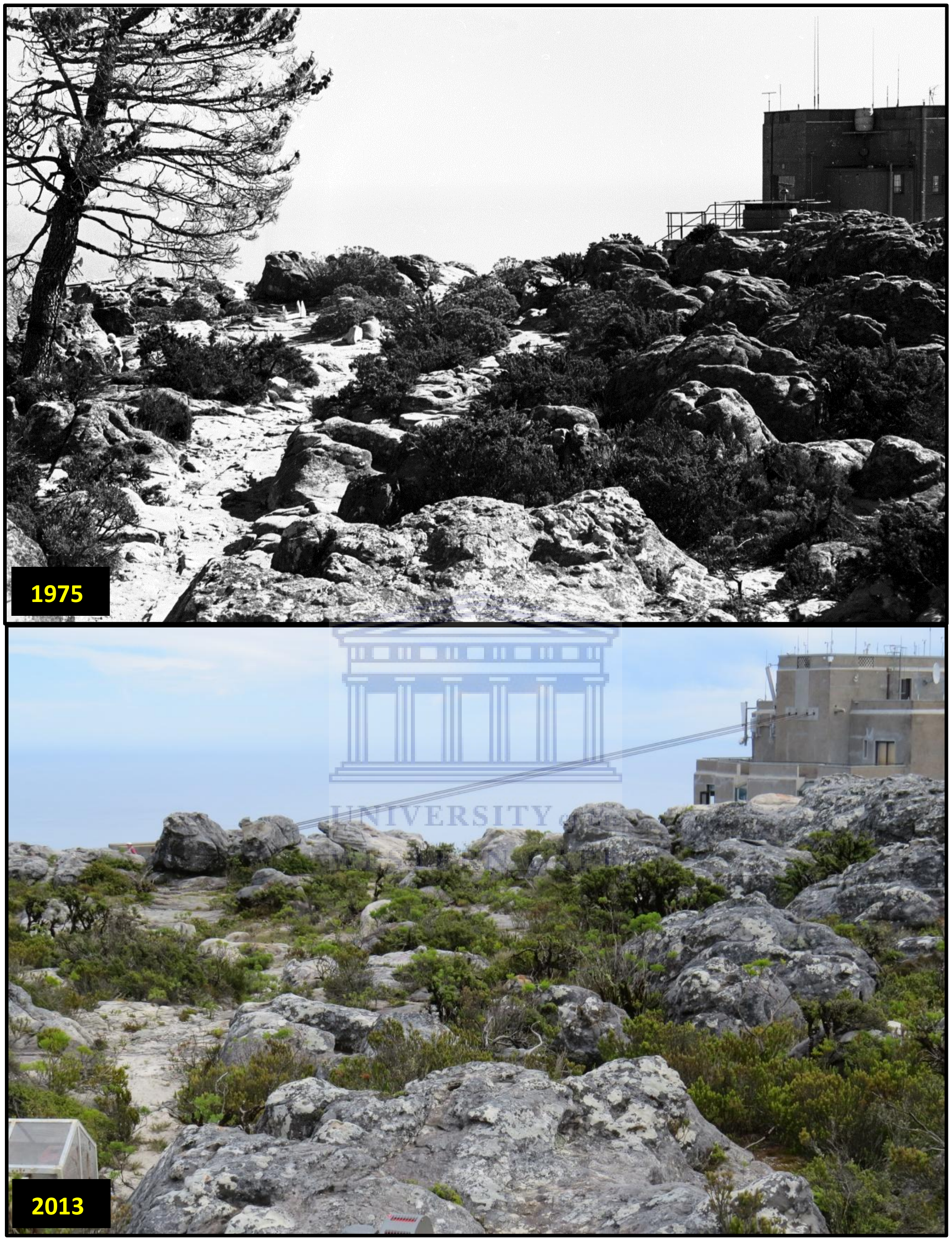

Figure 8. Past and present comparison (1975: Moll & 2013) of the main informal path known as 'Eloff Street' leading from the Upper Cable Station. The pine tree present in 1975 has since been removed. The old path scar is still evident in 2013 after 16 years of trampling protection even though the path is only seldom used today.

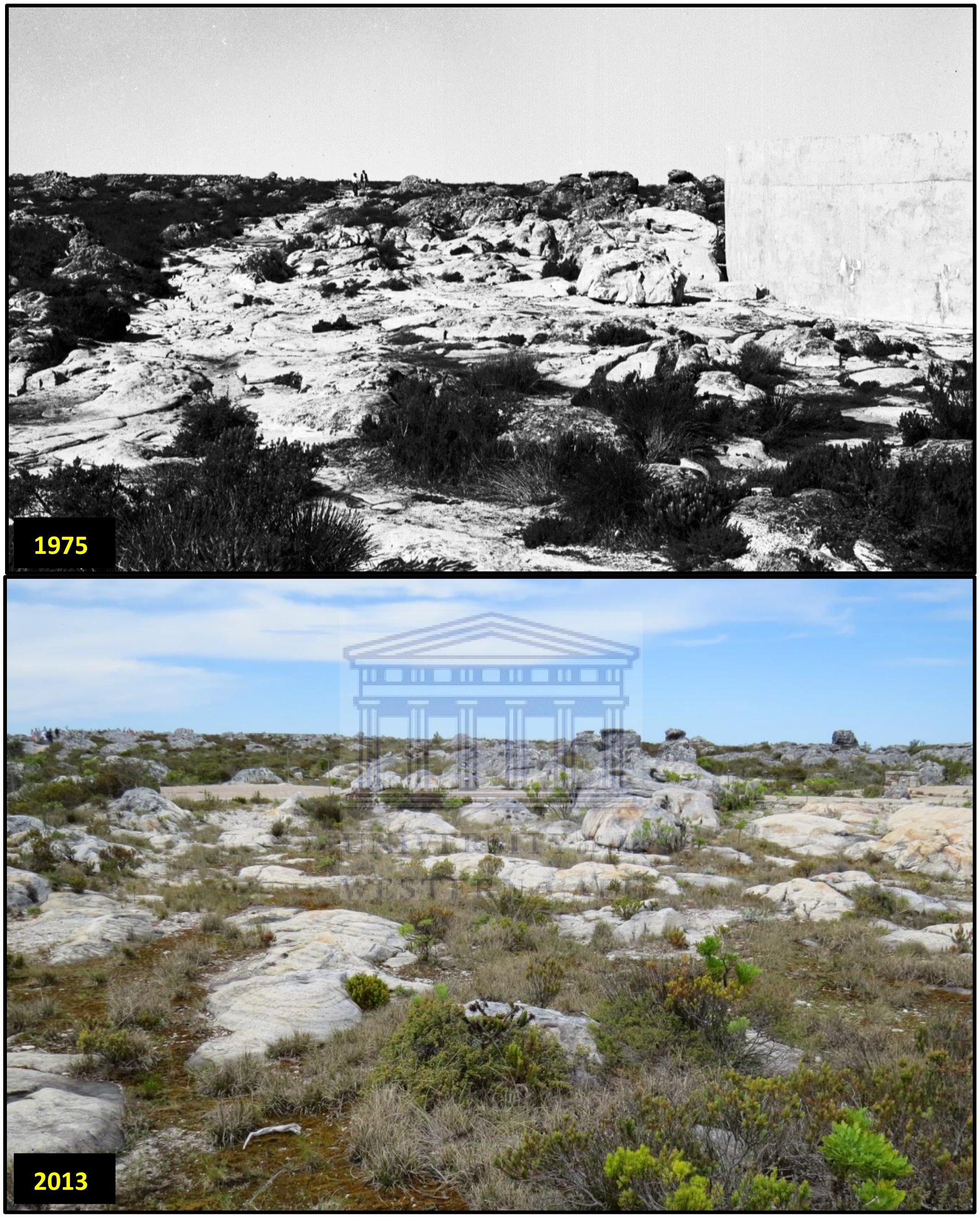

Figure 9. Past and present comparison (1975: Moll & 2013) showing the old reservoir and main informal known ('Eloff Street') in 1975 (Moll) and path and reservoir scars still evident in 2013 (left and right hand side of the image respectively). Notice the poor regeneration of vegetation on the rocky surface during the 16 year period. Also note the lack of restioid and high cover of Moss in 2013; a precursor to regeneration of the vegetation.

Figure 10. Example of the old informal path known as 'Eloff Street', still evident within the restricted access portion of the study area. Recovery of restioids in the centre of the path indicates that the path is not used by visitors anymore.

It is clear that disturbance through trampling leads to a more resistant complement of species since these are the first to re-colonize the impacted area. Studies in Yosemite National Park, California, indicate that species associated with informal paths leads to a higher number of 'resistant 'species (Foin & others 1976; in Leung 2011). Globally, paths result in an increase in the amount of ruderal species, nitrogen-demanding and indicators of basic conditions (Godefroid & Koedam 2003). Studies in heathland vegetation, adjacent to roads in the UK, show that grass abundance is higher in these areas, and can be attributed to the relative competitive advantage of species under conditions of eutrophication (Angold 1997). Godefroid & Koedam (2003) found that soil compaction was high along both sides of paths in forests; most likely an effect created during path construction, which leads to the disappearance of the most vulnerable species. This shows the significant difference between covered versus uncovered paths, particularly between indicators of basic reaction versus nitrogen-demanding species (Godefroid & Koedam 2003). Duliére et al. (1999) showed that dolomite lime is responsible for the appearance of nitrogen-demanding species.

Construction of paths using cement raises concern of the effects of calcium, magnesium and other cations leaching into soils from the cement. The soils on Table Mountain have a low pH - as is the case for the study site (Moll et al*.* 1978) whereas cement can have a pH as high as 12.5, with about 60% comprising CaO as well as of Mg, Na and K (Collis, pers. comm. 2013). Acidic soils have a lower tolerance to calcium input since such soils have a higher solubility (Jeffrey 1987, Epstein 1972; in Mustart & Cowling 1993) and species not adapted to alkaline conditions could experience nutrient deficiencies and high mortality (Mustart & Cowling 1993). Furthermore pH increase can increase plant composition up to a minimum distance of 10 m from the path (Godefroid & Koedam 2003). It is therefore probable that the weedy species associated with past trampling disturbance may be further maintained through calcium leaching from the cement pathways constructed prior to 1997 (Figure 11).

As rain and seepage water (that has a very low pH) continually makes contact with cement, this leaches Ca, Mg and small proportions of Na and K from the cement into the soil (Collis, pers. comm. 2013), the effects of which have not been properly researched in fynbos and certainly not on the Western Table (Moll, pers. comm. 2012). Increased levels of Ca, Mg, Na and K leached into the soil could possibly cause an increase in soil pH. As soils become more alkaline the solubility of certain elements in the soil is increasingly lowered, as well as the rate of absorption by plants (Salisbury & Ross 1992). This is particularly true for elements such as Fe, Zn, Cu and Mn since they form precipitates (in the form of hydroxides) when at high pH (Salisbury & Ross 1992).

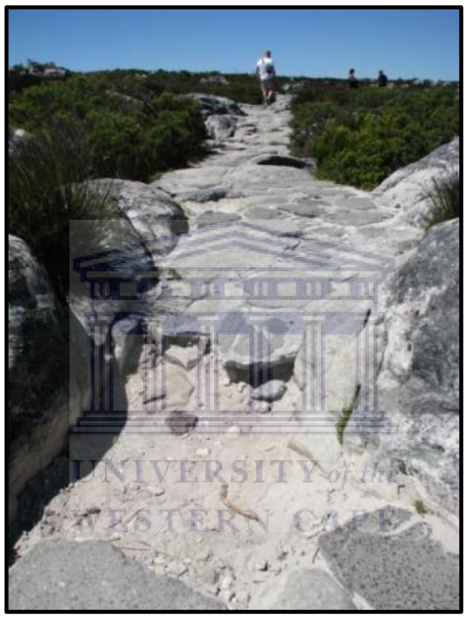

Figure 11. Cement pathways in slightly lower traffic areas further from the UCS, constructed before the 1997 upgrade, are susceptible to erosion, and may be influencing the soil pH and associated plant species associations along the paths.

Salisbury and Ross (1992) also point out that as a result of the mostly alkaline soils in the Western United States; plants often suffer chlorosis due to Fe-deficiency. In a similar way the vegetation on the Western Table may already be under a degree of stress from the existing cement paths and from the removal of previous cement/concrete structures, and the poor removal of fine concrete debris (Moll & Emms, personal observations). In the case of the Western Table observations on the rate of cement erosion holding the copper markers (used to mark the permanent plots) are that the cement used to hold these in place has eroded by 2–3 mm over the 33-year period (Figure 12). This is approximately 5–10 % of the volume of cement used and may therefore have an important influence on the soil chemistry on the Western Table.

Figure 12. The original copper markers used to mark the permanent plots were cemented into the sandstone rock and mixed with sandstone grit. Note the 'cement' erosion line on the marker, where approximately 2 – 3 mm has eroded. This shows that that considerable erosion and leaching of cement has taken place over the 33-year period. Cement and concrete occurs in the form of the path networks (both new and old) and very large amounts of debris on the Western Table.

Disturbed areas are also known to act as landscape conduits for weed species. Esler & Milton (2006) have made reference to this dilemma within South Africa's road reserves. The same scenario can be applied for paths and high tourist traffic areas. The most disturbed areas, in addition to plots located closest to or across paths, would be expected to have a higher weed cover; or at least presence thereof. Over time, with protection from trampling, it would also be expected that weed species will not have a competitive advantage over the natural flora on the Western Table; these would, therefore, reach a higher attrition rate with lower levels of disturbance.

Informal paths also lead to fragmentation of habitat, impeding the movement of small mammals and insects and act as a node for the spread of exotic species (Foin & others 1995; in Leung 2011). Informal paths also expose plant roots and, therefore, increase susceptibility to water-stress (Marion & Leung 2001). The aforementioned authors have also noted that in areas with slow recovery rates, disturbance can impact negatively on rare and/or endangered species and damage sensitive resources. The presence of zones with shallow soils on the Western Table means trampling is more likely to cause long-term damage when tourists traverse these zones and this leads to slow recovery because the substrate becomes eroded and loses what little soil there once was. The high altitude marsh areas on the Front Table, particularly the Western Table are also likely to be highly sensitive and have slow recovery. This is due to the accumulation of organic matter and more specifically the 'pseudo-peat' layers in the low nutrient Table Mountain Sandstone derived system, which could cause long-term damage through trampling. Loss of soil in nutrient poor environments should, in theory, result in slow recovery due to low nutrient availability. Table 1 provides a synopsis of the potential impacts at play on the ecological and social environment.

Table 1. Impacts at play on the Western Table and associated ecological and social effects (adapted from Marion & Leung 2001).

		Effect	
Impact	**Cause(s)**	**Ecological**	**Social**
Trampling	Tourist traffic	Erosion of substrate Destruction of vegetation	Aesthetic: old paths cause scarring of the landscape
Widening	Path flooding	Leads to side-trials	Aesthetic: Annoyance to hikers
Fire	Discarding of cigarettes in undesignated smoking areas	Potential to cause frequent fires in the future	Aesthetic: burnt landscape; Annoyance: ash acts as an eye irritant
Change in species composition	Calcium leaching from cement path construction	Probably contributes to the higher number of resistant species and decline in species diversity	Aesthetic: gradual decline in species diversity

Apart from trampling having an erosive impact on soils, there are indirect impacts - such as changes in hydrological flow patterns and soil moisture levels (Forman 1995; in Leung 2011). Formal paths, however, may have the same effect. It is well known that the path system on the Eastern Table of Table Mountain undergoes regular flooding due to the flat topography and impermeable underlying rock with shallow soils. This has the effect of forcing tourists to walk alongside the existing paths, leading to the development of side-trails, and thus impacting on the adjacent intact vegetation. Some of the problem areas have been dealt with in the form of effective, narrow, wooden boardwalks - allowing tourists to stay on the paths (Figure 13).

Figure 13. Raised wooden boardwalks meandering through *Elegia mucronata* dominated wetlands on the Eastern Table are an effective management tool that prevents the widening of paths where 'pooling' occurs. Narrow paths are ideal for low traffic areas.

The impacts imposed by trampling have certainly influenced the plant community structure on the Western Table. The communities recognized by Laidler et al*.,* (1978), for example, in their phytosociological study of the Upper Table, include similarities with Coley's study area. In their description of the plant communities they emphasized several species of importance, including *Cliffortia ruscifolia*, which was considered a reliable indicator of disturbance, in particular after fire. However, the disturbance at this time would have been anthropogenic and after trampling the species becomes dominant along with species such as *Peucedanum galbanum* (Laidler et al*.* 1978). Another important species, which Coley also made reference to, was the endemic *Thamnochortus nutans,* due to its restricted distribution on Constantiaberg and the Front Table. It was noted that the citing of the UCS had led to the *"very serious degradation of the vegetation of the Upper Plateau",* and further, that *Thamnochortus nutans* was threatened as a result. This species is listed as vulnerable according to the Red List of South African Plants (2012) because populations occur in areas frequented by hikers and are, therefore, subject to trampling pressure. Also the subpopulation on the Constantiaberg is fragmented by a tar road and radio tower (Red List of South African Plants 2012).

2.2. Fire and disturbance as a driving force in fynbos and the Table Mountain National Park

The Cape Peninsula forms the epicentre of the Cape Floristic Region (CFR) as a biodiversity hotspot and contains a total of ~2 285 plant species in a 471 km^2 area, and is home to 90 endemic plant species (Trinder-Smith et al*.* 1996). Table Mountain alone, which comprises 57 km^2 (Cowling & Richardson 1995), supports ~1 500 plant species, and ranks as one of the planets most biologically significant hotspots (Pauw & Johnson 2002). At a broader level the CFR is significant since it is recognized as a distinct 'floral kingdom' (Good 1974; Takhthajan 1986) that lies at the tip of the African continent, famed for high species richness relative to its size when compared to other parts of Africa (Goldblatt & Manning 2002). In an area occupying

90 000 ha and less than 4% of the African subcontinent there are an estimated 9 000 vascular plants, with almost 69% of these being endemic (Goldblatt & Manning 2002). This translates as 44% of the 20 500 species occurring in southern Africa (Arnold & De Wet 1993; in Goldblatt & Manning 2002), making the CFR a biologically important area. The species richness, per area, of the CFR is comparable to the wet tropical areas of the world rather than other temperate areas (Goldblatt & Manning 2002).

Maintaining this biologically important area in the Table Mountain National Park is a challenging task, as factors such as fire, a keystone ecosystem process for the existence of fynbos, and nutrient recycling and external inputs needs to be managed to ensure the regeneration of fynbos, whilst not posing a risk to human safety. Keeping the fire interval balance is challenging since many houses are situated along the perimeter of the Park and are at risk from uncontrolled fires. As a result many areas of fynbos have become overprotected despite the importance of fire to ensure its long-tem survival (Moll pers. comm. 2012). Since Peninsula fynbos typically requires a burn frequency of 5-40 years with an average of 12-15 years (Cowling & Richardson 1995) much of these unburnt areas on the Peninsula (and in the Fynbos Biome) require immediate, controlled burning to regenerate them and prevent extinctions. Further, the Front Table contains unburnt areas in need of fire, namely wet fynbos, which can tolerate a shorter fire interval while dry-land fynbos requires a longer interval. As for the nutrients there are aerial inputs from industrial pollution being deposited in rain (Brown, Mitchell & Stock 1984; Stock & Lewis 1986) as well as nutrients that have been and continue to be added by people (e.g. in cement and concrete, as well as litter and ’body’ materials). While such inputs are unseen they are likely to influence the plant communities in the long-term.

The study area does not support many large shrubs and members of the Proteaceae characteristic of many fynbos communities, but these are present nearby (e.g. *Leucadendron strobilinum* and *Protea cynaroides* at the top of Platteklip). This could be attributed to several, factors including shallow soils and the lack of fire. It seems unlikely that shallow soils would account for their absence as there are patches of deeper soils, which in all likelihood would support Proteaceae. It is more probable that the absence of taller proteoids is due to the long period between fire(s) since this trend towards loss of large shrubs in fynbos usually results from fire intervals which are either too short or very long (Bond 1980; van Wilgen 1982; in Schwilk et al. 1997) on the Upper Table.

The long fire interval (at least 80 to 90 years) on the Western Table is a concern in terms of maintaining biological diversity of the area, since the lack of this keystone process is likely to result in gradual decline in species diversity in the longer term. It is not known what the vegetation composition was like in the decades preceding the Coley's (1977), and others, study of the vegetation. It may be that the vegetation was similar to the present state in terms of the major plant groups such as restioids and shrubs, and that the high moisture levels has allowed for prolonged survival of these groups, since extended periods of drought are highly unlikely in such an environment. However, since certain species have fixed life spans, including seed survival, it can be surmised that local extinctions would have taken place without fire disturbance.

Disturbance is generally accepted as an important driver of species diversity in species-rich communities (Connel 1978; in Cowling et al*.* 1992). Disturbance is defined here according to

Cowling et al. (1992) as *"a process to prevent the exclusion of weaker competitors."* This means that not only fire, which is the main disturbance in fynbos, can be attributed to maintaining species diversity. Trampling is the main disturbance regime on the Western Table and is therefore expected to play a role in maintaining species diversity provided the intensity is not too high. A contentious hypothesis regarding disturbance is the intermediate disturbance hypothesis (IDH). The hypothesis states: *"diversity of competing species is, or should be expected to be, maximized at intermediate frequencies and/or intensities of disturbance or environmental change"* (Fox, 2013). Cowling et al. (1992) cite three studies (Huston 1979; Walker & Peet, 1983; Denslo 1985) that provide theoretical and empirical evidence that some intermediate disturbance will maximize species diversity. However, since then it has been reported that *"there is little support for the intermediate disturbance hypothesis in fire-prone communities"* (Schwilk et al. 1997), and more recently (Fox, 2013) it has been argued that the IDH has been refuted on both theoretical and empirical grounds. Fox (2013) states that empirical studies, including tightly controlled experiments, only rarely result (<20%) in a humped diversity-disturbance relationship, and further that the three major mechanisms thought to produce a diversity-disturbance relationship in theoretical studies are logically invalid and don't predict what they are thought to predict. Disturbance and environmental fluctuations, explains Fox, can affect species diversity but for different reasons than are commonly recognized. Fox goes on to state (from Hall et al. 2012) *"…insofar as the qualitative form of the diversity-disturbance relationship is determined by other variables, then humped diversity-disturbance relationships have no special empirical significance, being just one among many possibilities*."

2.3. Techniques for assessing vegetation change over time

Following the initial trampling impact study on the Western Table (1977), Coley made several concluding statements in his report concerning the impact of trampling and the future fate of on the Western Table. These included a critique of the methodology and summation of the baseline findings. Very few conclusions were drawn from this initial study since the objective was to collect baseline data for the purpose of future comparisons. Furthermore no phytosociological table was compiled. In Coley's words, *"It was decided to undertake a survey of the species present on the Western Table and to assess their present status and physical condition. A careful record was to be kept of all data so that direct comparisons could be made from time to time. Thus there would be some basis for the formulation of a plan to control the movement of the people within the study area."* Thus the impacts and subsequent monitoring was installed for the purpose of assessing trampling impacts and for providing a basis for improved management of the area.

According to Burden & Randerson (1972), the effects of trampling are typically studied by measuring changes in the edaphic and floristic environment; in either (1) identified areas of high intensity, where the equilibrium has been altered, or (2) in areas where trampling pressure is expected to increase and requires monitoring where potential deterioration is anticipated, or (3) areas with no trampling pressure in a state of equilibrium. The last measurement is used to gauge the desired state of an affected habitat in the immediate vicinity. The changes may be observed in short- or long-term. Important measurements include soil (e.g. chemistry, structure, compaction levels, depth and changes in litter) and vegetation (e.g. change in species cover, height and condition using percentage cover or Braun Blanquet cover scale in conjunction with time-lapse photography). The trampling pressure can be recorded by counts (Burden & Randerson 1972) or other means such as ticket sales. The data can then be interrogated using a correlation and ordination (Burden & Randerson 1972), and what is proposed here, transition matrices (Pontius et al. 2004). Transition matrices are typically used to analyze land change by comparing maps or landscape-level photographs from two (or more) time periods.

One of the potential problems with regard to long-term historical vegetation monitoring is the consistency and data collection method used by the various field workers. Although it may seem obvious that the method employed should be exactly the same for each sampling period, this was not the case in earlier times, when plant ecologists used their own methods (Mueller-Dombois & Ellenberg 1974). The Braun- Blanquet (BB) or Zürich-Montpellier phytosociological technique became a widely accepted method for vegetation analysis, with the introduction of the cover-abundance scale (referred from here as the BB cover abundance scale or BB method), providing a relatively simple yet quasi-quantitative system (Mueller-Dombois & Ellenberg 1974). A number of key phytosociological studies carried out in South Africa, and within the Cape Floristic Region included those by Taylor (1969), Moll (1969), Werger (1972, 1973a and 1973b), Mckenzie et al. (1977), Boucher (1977), Moll et al. (1984) and McDonald (1985).

Cover is defined by Werger (1974) as the aerial cover, or the area covered when the canopy is vertically projected onto the ground. The BB cover-abundance scale of species, which is based partly on cover and partly on abundance (Werger 1974), uses scale values (Table 2) that relate to a reference area, which is fixed by the size of the relevé (Mueller-Dombois & Ellenberg 1974).

Table 2. The Braun-Blanquet cover-abundance scale

Scale	Cover description
r	Very rare and with a negligible cover (usually a single individual)
+	Present but not abundant and with a small cover value (less than 1% of the quadrat area)
1	Numerous but covering less than 1% of the quadrat area, or not so abundant but covering 1 – 5% of the quadrat area
2	Very numerous and covering 5% of the quadrat area, or covering 5 – 25% of the quadrat area independent of abundance
3	Covering 25 – 50% of the quadrat area independent of abundance
4	Covering 50 – 75% of the quadrat area independent of abundance
5	Covering 75 - 100% of the quadrat area independent of abundance

The scale units 3, 4 and 5 refer to cover only, whereas the other units refer to cover and abundance (Werger 1974). Barkman et al. (1964 in Werger 1974) criticized the scale because the steps in the scale are not proportional to one another. He was particularly critical of scale unit 2 and included a several modifications, which Werger (1973a, 1973b in Werger 1974) adapted for vegetation surveys in South Africa (Table 3). Werger considered the adaption to be more suitable for survey of permanent plots, as follows

Table 3. Adaptation of the Braun-Blanquet cover-abundance scale by Barkman et al. (1964 in Werger 1974)

Scale	Cover description
2m	Very numerous, covering less than 5% of the quadrat area
2a	Covering between 5 and 12% of the quadrat area independent of abundance
2b	Covering between 13 and 25% of the quadrat area independent of abundance

The terms 'plot' and 'relevé' can be confused but essentially are distinguished on the basis of information assigned to the quadrat. Thus a plot refers to the quadrat as it stands in the study area and becomes a relevé once ecological and phytosociological observations are added (Gordon 1968; in Werger 1974). The term relevé can be used before the information is added but then the term takes into consideration the observational data that would be added later.

In the BB method species cover-abundance estimations are made for each species in the plots from a vertical observation point. The method can be used for both higher plants and for most moss and lichen communities (Mueller-Dombois & Ellenberg 1974). Additional information can be collected such as sociability but this estimation is not regarded as important, as Mueller-Dombois & Ellenberg (1974) explains: *"However, it has been found that sociability is a characteristic property of a species in most instances. Therefore it does not need to be recorded in normal cases."*

The matter of making estimations versus measurements may be criticized but the method has been recognized as the best way of collecting information for numerous plots within highly varied plant communities (Mueller-Dombois & Ellenberg 1974). The estimation method is more rapid than a more detailed measurement method and allows for more useful community classification or ordination analysis (Mueller-Dombois & Ellenberg 1974). The vegetation cover abundance data is usually represented as a phytosociological table, whereby the relevés are arranged according to species common to several relevés (Mueller-Dombois & Ellenberg 1974).

The dominant associations are described as communities whereas the less common species that fall outside the communities may form subcommunities (Mueller-Dombois & Ellenberg 1974). Species that are faithful to most relevés are referred to in terms of fidelity (Werger 1974). Certain species may be common to some communities or subcommunities, but differentiate between other communities or subcommunities, in which case these are referred to as differential species (Werger 1974). The main communities relate to the dominant species whereas the subcommunities may be related to less dominant or differential species. Once the communities and subcommunities have been identified, interpretation and description of the vegetation can be undertaken.

Vegetation dynamics can also be described and understood by a set of discrete 'states' of the vegetation in one area and a set of discrete 'transitions' between states (Westoby et al. 1989).Transitions in states occur as a result of natural events (e.g. fires and weather) or management 'action' (e.g. burning, trampling). Transition may occur rapidly or over an extended period. According to Westoby et al. (1989*) "A state is necessarily an abstraction encompassing a certain amount of variation in space and time."*

State-and-transition models (STMs) are useful tools for assessing monitoring data since the methods use reference points to determine change over time (Bestelmeyer et al. 2009). These are usually based on observations of temporally-related plant communities coupled with soil and climate data, that produce persistent structural and functional ecosystem attributes – (i.e. states – (Bestelmeyer et al. 2009), which can be applied to make predictions of future trends in the landscape, based on the disturbance regime tenure (Hoffman pers. comm. 2013). Concepts around STM's are well established, however the quantification of these is not as clear in terms of application (Bestelmeyer et al. 2009).

Another important aspect of STMs is that they determine the point at which plant community changes preclude autogenic recovery and require energy intensive measures to reverse (i.e. thresholds; Springer in Bestelmeyer et al. 2009). The assessment and monitoring data of STMs is aimed at preventing *"persistent degradation and target restoration actions where benefits are most likely to be realized."* (Bestelmeyer et al. 2009). In the case of Coley (1977) these objectives were targeted. An important question to ask at this stage is what the benchmark state of the communities on the Western Table is? In order to determine this, nearby communities which are undisturbed need to be chosen? The closest benchmark communities in Coley's (1977) plots are Plots 10, 11 and 12 and the undisturbed areas near to Plots 1 to 9. Reference communities were not sampled for Plots 1 to 9, yet observations of undisturbed areas provide some insight into what these communities should be gauged against in Section 1.4.

STM's are useful in their application for not only dealing with discrete states linked by sudden transition but also for summarizing vegetation dynamics; for example, recognizing changes in the underlying botanical composition of an area (Westoby et al. 1989). STMs are useful and practical tools for organizing information for management, and require catalogues of states and catalogues of transitions needed to make predications (Westoby et al. 1989). Such predictions may inform management of potential negative changes in states (Westoby et al. 1989). 'At-risk' communities are those that represent the consequences of increased vulnerability to transition (Briske et al. 2008; in Bestelmeyer et al. 2009).

CHAPTER 3: METHODOLOGY

Coley (1977) assessed the vegetation using two survey techniques; namely the Braun Blanquet phytosociological technique and aerial photography. These techniques were used to survey vegetation plots arranged in the vicinity of the UCS. Note I have used the term plot to refer to both positions and observational data for readability purposes, and have used the term relevé only in the phytosociological tables.

3.1. Sampling area

In order to monitor changes in vegetation through time Coley set up 12 permanently marked vegetation plots (Figure 5), of which three were fenced off (i.e. no access) exclosure plots (Figures 15 & 16). The purpose of the exclosures was to protect the vegetation and compare the non-trampled areas (exclosures) with the trampled areas. These were subjectively positioned at various distances from the UCS, so that the possible effects of trampling could be measured at various points - distance being a surrogate for trampling intensity (Figure 5). The sample plots were selected in such a way as to (1) cover areas of high intensity trampling and (2) to allow some assessment of possible future damage to areas relatively undamaged at the time. The objective was to measure the species present and to assess their status and physical condition. The survey was designed so that repeat assessments could be made into the future. Plots measured 4 m x 4 m, except Plot 5e (e = exclosure), which was roughly 2 m x 4 m. Plots were positions as follows (Coley 1977):

- Four plots approximately 115 m (Plots 1 & 2) to 140 m (Plots 3 & 4e) from the UCS, where vegetation was most heavily impacted (including two exclosures to monitor how the vegetation would recover when protected from human trampling). These were placed on the eastern side of the Western Table off the path leading to Maclear's Beacon (known locally at Eloff Street aka Adderley Street), the main city road in Johannesburg as most people tramping along the path were deemed to come from this city). Plot 3 was positioned immediately adjacent to the main path (Figure 5).

- Four plots (6e, 7, 8 & 9) were situated in what was considered to be intermediately impacted vegetation, approximately 175 m from the UCS (including one exclosure – Plot 6e). These were placed on the same side of the main path except Plot 8, which was within a meter or two west of the path. Plots 7 and 9 were placed immediately adjacent to the footpath.

- One exclosure Plot (5e) was placed on an informal pathway between these first two sites, approximately 150 m from the UCS. The three open plots (Plots 1, 2 & 3) and two exclosure (Plots 4 & 5) were placed within easy access of the UCS, restaurant and telescopes.

- Three plots (10, 11 & 12) were situated approximately 330 m from the UCS in an area of minimal impact. These were also placed along the eastern side of the main path (Eloff Street).

All plots (except exclosures) were marked with two permanent copper plates (± 25 mm x 10 mm x 10 mm) that were cemented into the bedrock and camouflaged using small stones and pebbles. The northern most plate of each plot was marked with a reference number corresponding to each plot whilst the southernmost plate was left blank. The two markers form a southern baseline for each plot, except Plot 8 where it forms the northern baseline.

For the purposes of obtaining a high level of detail Coley divided each of the non-exclosure 4 m x 4 m plots into eight 2 m x 1 m quadrats, and assessed these individually. For exclosure Plots 4e, 5e and 6e, three quadrats were placed inside and three outside (Appendix G). He constructed a tubular steel quadrat, with string forming 200 x 50 mm squares of 0.1 m^2 each. Thus the quadrat had a 2 m x 1 m grid reference system that was placed over the vegetation so that each square was assessed. The quadrat could be lowered (ground level) and then raised (±1 m) on three adjustable legs, so that the entire grid system was positioned horizontal to the ground. Coley included an evaluation of a single plot (Plot 1) based on a trial method involving detailed vegetation plotting and recording method, which has been included below. It should be noted though that Coley's data was compared during the subsequent studies, most notably this thesis. Furthermore the data sets are sufficient to explain and evaluate the state of the vegetation cover and condition at that time.

3.2. Plot assessment: cover abundance

Using the Braun Blanquet phytosociological technique Coley assigned a cover (all individual plants of a species considered together as a whole) rating to each species within each square. Their cover scale-units included Werger's aforementioned 2m adaptation (scale reference number 2 below). He also assigned a rating of condition and sociability, and average height for each species. Condition and sociability ratings were not recorded in this study since cover was regarded as the most practical and accurate measure of overall change whereas sociability and cover are largely encapsulated by the former, most commonly used, rating measure. Rock cover was not recorded as there was concern that the vegetation would be too damaged by people trampling in the plot to do the assessments. All species surveyed were assigned a reference number. The ratings were also applied as follows:

COVER

r	solitary, with small cover
+	few, with small cover
1	numerous, but less than 5% cover
2	any number, but with less than 5% cover
3	any number, with 5 – 25% cover
4	any number, with 25 – 50% cover
5	any number, with greater than 75% cover

Calibration for cover ratings: (1) = is cover more than ½ the quadrat or less? (2) = is cover more than ¼ the quadrat or less? (3) = is cover less than 1/5 of a quarter?

CONDITION

1	plant undamaged
2	plant slightly damaged
3	plant severely damaged
4	plant only just extant, or remaining parts limited to roots and/or rhizomes

SOCIABILITY

1	growing solitarily
2	forming clumps or dense groups
3	forming small patches or cushions
4	growing in small colonies
5	growing in large, almost pure population stands

In the 2010 the quadrat to single plot conversion (i.e. all quadrates collated to make one plot) of Coley's data was necessary so that the plots could be surveyed as 4 m x 4 m quadrats as opposed to the eight quadrats per plot method used by Coley. This meant that the eight 2 m x 1 m quadrat survey method was reduced to a single plot survey method. This conversion of Coley's quadrats into to single plots was performed by first converting the BB values to numbers within each quadrat as follows: r = rare = 0.01; + = present = 0.02; 1 = < 5% = 0.5; 2 = 5 - 25% = 0.25; 3 = 25 - 75% = 0.50; 4 = 50 - 75% = 0.75 and 5 = 75 - 100% = 1. The numeric values were then averaged for all quadrats within each plot using an aggregating function in the SaSFlora (1998 – 2013) data base developed by Roberts and Low ©. Mean values from the quadrats were rounded to the highest BB value when converting the data to single plot data. This was done so that the previously trampled vegetation (1977), which had low cover values, would be overestimated instead of underestimated and in doing so would therefore avoid any bias or underestimation of cover.

3.3. Plot assessment: photography

All 12 plots were photographed by Coley using two 35 mm SLR Asashi Pentax cameras with 50 mm lenses and a 2¼″ twin lens Yashica. Photographs were taken from a height of ±8 m using a 9 m extendable aluminium ladder, secured by ropes (Figure 14a & b). The ladder was angled using the supporting ropes so that the plots could be captured on camera without obstruction. For each plot a single photograph of the whole plot, in addition to eight photographs of the respective quadrats, were taken. The 'whole plot' photographs were scale-referenced using 4 x 2 m survey range rods (with 500 mm divisions) placed in the centre of the plots in the form of a cross. All photographs were developed as colour transparencies and black-and-white prints – so that future comparisons could be made by setting up two slide projectors and viewing the respective sampling periods simultaneously. A different photographic technique was used for the 2005 and 2010 survey, consisting of a boom system devised by Cilliers et al. (2004) (Figures 14a & b). The system consists of a 6 m aluminium pole that pivots on a cross bar, so that a significant height can be gained to trigger a camera suspended on the highest end. For this set of images digital photographs were taken using a Canon EOS 500D digital SLR camera. The plot photographs positions were determined in the field with the aid of the printed 1977 plot photographs. These were printed from the photographic slides. Lastly, it is important to note that recent technological developments in aerial photography using GPS controlled Unmanned Flying Vehicles (UAVs), or drones, have replaced the pivot pole systems. Drones can be operated in up to 50 km/hr winds and can be pre-programmed with coordinates to 0.5 m accuracy.

Figure 14a & b. The rope-suspended ladder photography system used by Coley during 1977 (Figure 14a) and the boom system used in 2010 (Figure 14b).

3.4. Survey history

Following Coley's initial survey the plots were re-surveyed at varying times and with different degrees of detail (Table 2) by Aubin (1985); van Coller (1988); Kerbelker (1988); Emms (2005) and my study (2010/2011). Aubin carried out the same data collection detail for plots (i.e. surveyed eight 2 m x 1 m transects per plots) whereas subsequent fieldworkers treated each plot as a single 4 m x 4 m quadrat. The rationale behind this is that the original survey method using eight quadrats per plot is exceedingly tedious, and does not necessarily provide a more accurate level of detail if one considers the efficacy of the BB technique, and its application here relates to a relatively small (4 m x 4 m) plot. Moreover, since van Coller (1988) and

Kerbelker (1988) treated each plot as a single 4 m x 4 m quadrat, and their data was deemed more accurate than Aubin (1985), a repeat of the same methodology carried out in 1988 was therefore required in 2010. Thus Coley's eight 2 m x 1 m transects per plots were amalgamated so that these could be compared with van Coller (1988) and Kerbelker (1988) and Emms (2010/2011). This would also ensure ease of repeatability for future monitoring. A summary of the survey history is represented in Table 4.

The original plan was to sample at three points from the UCS (distances were used as a surrogate for trampling intensity) it seems that Plots 1 – 9 all had the same high intensity trampling impact since these were all fairly close together, whereas Plots 10 to 12 were located in a separate area much further away. Trampling intensity is therefore more appropriately separated into two trampling intensity zones, namely high (Plots 1 to 9) and low (Plots 10 to 12) intensity. A key change that has occurred, following the upgrading of the UCS in 1997, is that the off-path tourist traffic has become minimal due to the construction of a formal path system. This despite the fact that the new/current cable cars have a passenger capacity of 65 passengers each (TMACC 2011). Light barriers and signage were also put in place, thus ensuring tourists remain on the paths (Figure 15). Lastly, while the objectives of the 1977 survey were intended to monitor the impacts of human trampling, the objectives of this study were to compare the state of the vegetation in terms of recovery and to determine the major trends. It was therefore decided that it would be of utmost importance to draw conclusions from the current state of species diversity.

Table 4. Survey history of Coley's permanent vegetation plots on the Western Table

Year	Fieldworkers	Plot survey method	Plots surveyed	Plots photographed	Photography method	Raw data	Ordination table compiled	Path network in place	Restricted access to paths only
1977	Coley & Moll	8 quadrats per plot	All	All	Ladder	Available	No	No	No
1985	Aubin	8 quadrats per plot	All except Plot 11	All except Plot 11	Ladder	Available	No	No	No
1988	van Coller & Kerbelker	Whole plot quadrats	All	All	None	Available	Yes	Yes (basic)	No
2005	Emms	Whole plot quadrats	All except 2 & 3	All except 2 & 3	Boom	Available	No	Well defined	Yes
2010	Emms	Whole plot quadrats	All except 2 & 3	All except 2 & 3	Boom	Available	Yes	Well defined	Yes

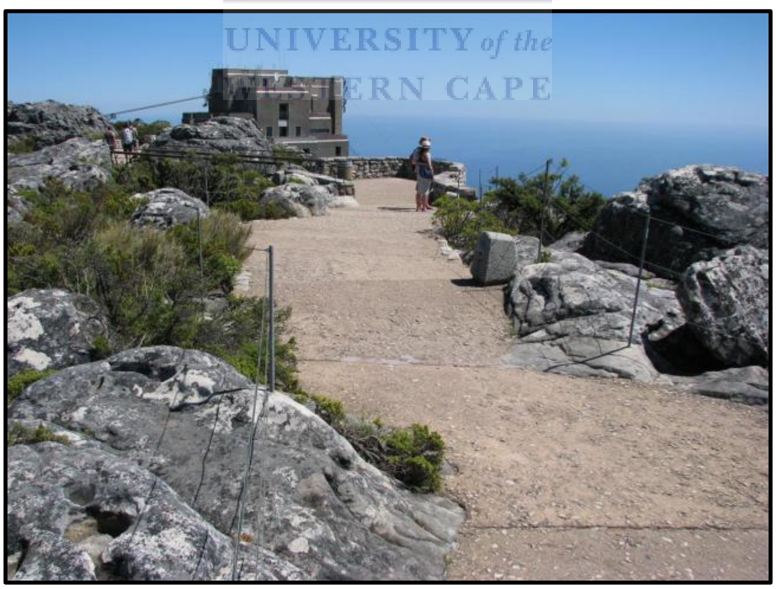

Figure 15. The main path system leading from the UCS, showing the marker barriers on either side of the path, which aim to prevent trampling of the natural vegetation.

3.5. Photographic records: 1977 versus 1988 and 2010

The photographic records were aimed at providing an evidence-based comparison. The visual comparison is considered as an effective management communication tool since it provides a simple and rapid evidence-based presentation versus a complex and abstract data-based presentation, which is open to interpretation. Furthermore the visual presentation can be used without mentioning individual species and phenology, which can be confusing to managers lacking detailed knowledge of the local flora and an understanding of the ecological dynamics.

Plant groups have thus been used as a means of providing a clearer description and broad interpretation of the visual records. At this point two approaches were employed; the first being a broad classification, which assigns a basic visual cover estimation for rapid comparative purposes, and the second being a more tedious, albeit more accurate, transition matrix. The purpose of executing both approaches was to determine whether the more detailed method could be determined as an equal in terms of accurately recording vegetation change over the various time periods. A more rapid assessment method would be more useful and accessible approach could potentially be applied elsewhere. The two approaches are described below:

For the first approach it was possible to make percentage estimations, from an aerial perspective, of rock, sand, restioid, ericoid, graminoid, Moss (soil biogenic crust) and dead material (litter and free-standing) cover for each plot photograph for the 1977, 1988 and 2010 periods. The rationale behind using percentage estimations instead of BB values is twofold. Firstly I consider the Braun Blanquet method misleading when working with small plots (4 m x 4 m) since the values provide leeway of up to 25% estimation (e.g. BB value 3 = 5 – 25%) error.

Secondly the Braun Blanquet method, although recognized internationally as a sound ecological method in terms of phytosociological studies, is not a familiar method and may be disregarded when needing to communicate plot data to a broader audience (i.e. various tiers of SANParks management and the public). Further, the method is used to describe and map vegetation at the landscape level and is not typically applied for detailed studies such as Coley's. It must be emphasized that the estimations are based on the visible aerial cover for all the above categories, which may change according to the vegetation growth and possibly even seasonally. Species may, for example, occur between rock cracks and thus influence the visible rock surface area whereas the actual surface area may be different. It would be expected that rock cover would be higher in the previous heavy impact period (i.e. 1977) and that this would decrease with vegetation recovery. Another expected trend was a slight recovery in vegetation cover subsequent to cementing of the some of the path sections prior to the 1997 upgrade (between 1977 & 1988). The visual estimation and actual cover counts of the categories are provided and discussed below. The various cover categories could be made out relatively easily apart from the dead material. In most cases it was possible to determine dead individuals or parts (e.g. branches and stems), however this was more difficult when classifying dead material of restioids from the 1977 and 1988 photographs. The categories that were assigned were rock, sand, restioid, ericoid, graminoid, moss (soil biogenic crust) and dead material (litter and free-standing).

For both approaches (i.e. cover estimation and transition matrix) a series of steps were carried out before the photographs could be compared on a 'like-for-like' basis. This was achieved by first scanning the original photographic slide images from 1977 and 1988 using a Nikon Super

Coolscan 5000. The images from 1985 were scanned using an EPSON Perfection V750 Pro. These were saved as high resolution TIFF in large scale (A3) format.

It should be borne in mind that a shortcoming of the photographic data set lies in the differences in variables such as photograph angle, fixed point, resolution, lighting, elevation distance, camera make and portion of plot captured by the photographer. This meant that matching the images was extremely tedious, owing to the adjustments required, which related to the aforementioned variables. However, it was possible to match the 1977, 1988 and 2010 images using Photoshop CS4. 11.0.2 (2008). This involved a series of steps; starting with standardizing the image resolution of each image to 300 DPI (dots per inch). The standardized images were then saved as high resolution TIFFs (Tagged Image File Format). The image widths of all three images were then re-sized to the same width as the smallest width image. In order to cross-reference the image sizes, known points on each image were measured off fixed points. Rocks were used, with specific visible features, such as intersections in cracks or small irregularities and erosion holes, used as reference points. Pairs of images were matched against the original (1977) image. In other words, the 1988 image was matched against the 1977 image, followed by the 2010 image being matched against the 1977 image.

Using the known distances from each image pair (e.g. 1977 & 1988 or 1977 & 2010), the measure distance from the original (1977) image was divided by the repeat image (1988 or 2010) and multiplied by the common standardized width distance. The calculated distance was then substituted as the repeat image (1988 or 2010) width distance. This allowed for identically matched image pairs, that could be overlaid (i.e. dragged), with the repeat placed onto the original image. Using the transparency, drag and rotate tools images could be aligned and saved as composite matched layers. Once the composite matched images were compiled, only relevant ‘like for like’ captured information was cropped. The matched images were saved as high resolution TIFFs and low resolution JPEGS. The JPEGs images widths were standardized to 24 cm for importing into Microsoft PowerPoint (2007).

Once the images were identically (i.e. spatially) matched, a grid overlay of 15 cells across and 10 cells wide was positioned over each matched image set (1977, 1988 & 2010) (Appendix D). This resulted in a set of images for each plot and the three time periods (1977, 1988 & 2010) having grid cells that corresponded spatially for the three respective time period images. The size of the grid cells varied according to the image sizes. The identically matched grid overlay images were imported into Microsoft PowerPoint (2007). Each plot therefore included three slides for each respective time period. Cover categories were then assigned to each grid cell on each of the images using colour coded dots and a cross-tabulation matrix or transition matrix is used to detect land category changes over time (Figure 16). The cover categories included rock, sand, restioid, ericoid (all non-restioid forms), graminoid, moss (soil biogenic crust) and dead material (litter and free-standing). The categories covered all the classes of cover, which meant that the total (1) estimated percentage cover and (2) tallied cover counts added up to 100% for each plot image across the time-series.

Since the data deals with counts, comparing the same spatial area over three time periods (1977, 1988 & 2010), the cover change could be determined for each time period from the tallied counts for each of the seven cover categories. Since each grid cell relates exactly to the next, between each time period, the data is non-random. Statistical comparison of non-random data cannot be carried out in terms of statistical significance since there is no uncertainty or random probability. Cover change can be determined. However, there would not be any statistical comparison between the difference in cover between 1977, 1988 and 2010. Instead, the importance of the observed changes must be evaluated in terms of practical significance. In other words, what does the change in cover or the degree in change of cover mean in terms how the vegetation has changed over time. These trends were therefore represented graphically in Section 4.6.

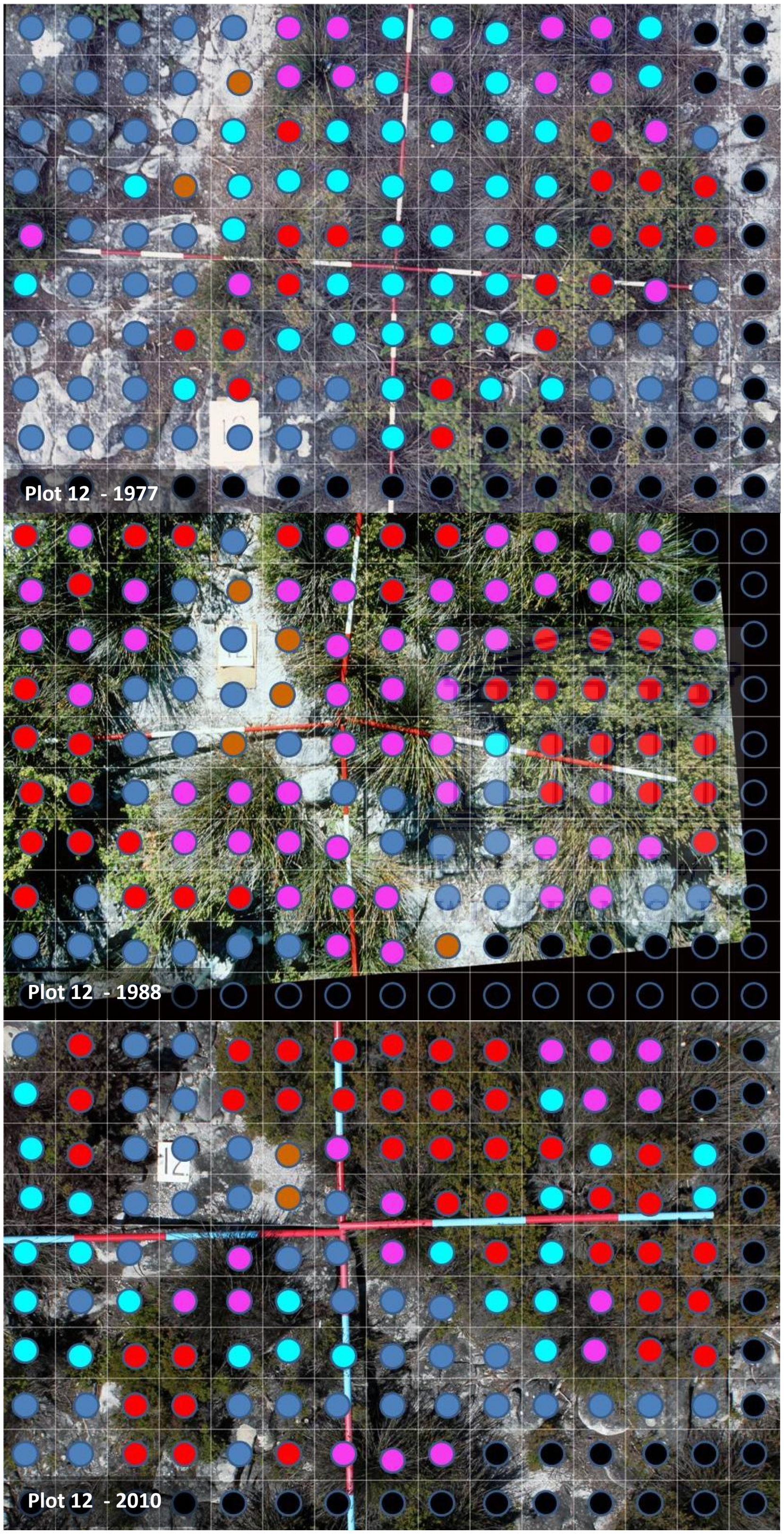

Figure 16. Example of a transition matrix of the photographic time series of Plot 12 recorded in 1977 (Coley), 1988 (van Coller & Kerbelker) and this study (2010). A grid cell overlay of 15 x 10 cells was applied to each plot image. The difference in cell counts was calculated for the three time periods by counting the change in each category.

CHAPTER 4: RESULTS AND DISCUSSION

4.1. Cover abundance plot data

Interpretation of the cover abundance data is complex when considering the history of the long term monitoring over time. Firstly the trampling regime has changed since 1997, when all (remaining) plots effectively became exclosures. Unfortunately the upgrade resulted in the loss of Plot 3 as these were paved over. Plot 2 was searched for on several occasions and eventually found towards the final stages of this thesis on a final site visit. It is not known whether any disturbance occurred within the remaining plots closest to the construction area (i.e. Plots 1, 2 & 4), nevertheless actual recovery of the trampled vegetation in Plots 1 to 9 would have only begun at this point when the trampling pressure ceased. Secondly the fine-scale heterogeneity of the flora makes it difficult to recognize and evaluate communities for detailed comparative purposes. A brief synopsis of a study by Mustart et al. (1993) gives some insight into this dilemma. In their study they showed that community pattern can be determined much more accurately using small plots (4 m x 4 m i.e. 16 m^2) in fynbos phytosociological studies. Their study showed small plots are better suited for determining small scale pattern, because they better reflect "*habitat heterogeneity*", than large plots. Large plots covering heterogeneous habitats capture the information from transitional and even adjacent communities, whereas small plots are more likely to pick up the small scale subtleties within the observed communities. However, in Coley's plots several communities were identified, yet sub-communities or subcommunities were less discrete. Several subcommunities were, however, identified.

Fine–scale heterogeneity of the flora should also be explained, in part, in relation to fine-scale habitat heterogeneity. For example exposed, well drained and shallow soiled rock fissure niches usually support succulent flora such as *Lampranthus falciformis* and *Crassula coccinea*. The aforementioned habitat distinction is the most obvious, yet the remaining habitat has subsurface moisture patterns which are extremely difficult to measure in such a heterogeneous habitat. Soil depth, although an important environmental variable, would not explain unseen subsurface moisture patterns based on an equally complex subsurface micro-topography. Thus in order to detect any trends over time, the dominant and high fidelity species were used as key indicators. These are discussed under the *'Major trends in species'* section below.

Thirdly, there is the question of natural vegetation change over time in the absence a human-induced trampling regime. The response of the vegetation communities and individual species in the absence of fire, spanning several decades, specifically in a fire-prone system, is considered to provide some leeway for separating the two disturbance regimes. In other words the lack of fire on the mountain over the entire sampling period has kept the integrity of a single disturbance regime, which is trampling, intact.

Lastly, there is also the question behind the validity of the data collection by various field workers mentioned previously. Of particular concern are the missing vouchers specimens from Coley's (1977) initial survey. However, it is conceded that most of the dominant species are common species, which would not be easily mistaken. Some of the grass species identifications for example are questionable since names provided in 1977 and subsequent years do not match well with the 2005 and 2010 sampling periods. In addition data collected by Aubin (1985) and then van Coller (1988) and Kerbelker (1988) are regarded as less accurate than Coley (1977) and my (2005 & 2010) collection**.** Based on personal communication Moll described Coley as a meticulous worker with attention to detail, as he was a mature student who previously practiced as a draftsman. Further there are several mistakes evident in the 1985 and 1988 re-surveys, which can almost certainly be attributed to inaccurate sampling. For example, several dominant species which were present in the same plots in 1977, 2005 and 2010, were not recorded in 1985 and 1988. In other instances the same species, which were present in 1977, 2005 and 2010 were present in 1985 yet absent in 1988 or vice versa. A key example is *Restio perplexus*, which was present in Plot 1 across all sampling periods except in 1988 (Appendix A). The same species was present at relatively low cover (BB cover = 1) in Plot 5 for 1977, yet absent at all remaining sampling periods except in 1988 where the species was recorded as having high cover (BB cover = 3) which suggests that a mistake was made in 1988 - perhaps a misidentification. The 1985 and 1988 data sets were thus treated with this in mind when comparisons were made with the remaining data sets of 1977, 2005 and 2010. In summary the most accurate data sets are from the 1977 and 2010 sampling periods and are therefore used as the primary surveys for analysis. In contrast the photographic records can be used across all time periods since these are accurate snapshots of the vegetation.

4.1.1. Sampling periods and effects of path construction

The sampling frequency, which was not designed to be monitored at fixed periods, forms an interesting serendipitous pattern. A period of eight years separates the first sampling period (1977) from the second (1985), followed by a three year gap (1988) and then an eleven year gap until the major upgrade of the UCS (1997), when the three exclosure fences were taken down. At this point there would have been inevitable disturbance by contract workers Plots 1 to 9. The disturbance would have been more intense closest to the UCS, in particular Plots 1, 2 and 3. There is ample evidence of such disturbance in the form of cement debris scattered in the vicinity of Plots 1, 2 and 3, and of Plots 4e and 5e. Some of the debris in Plots 4e and 5e must have been from the cement which supported the exclosure legs, which were subsequently broken up when these were removed. Aerial imagery (Figure 5) shows a heavily disturbed area just south of Plot 1, where the reservoir once stood.

The removal of the exclosures was unfortunate as these were supposed to remain for future comparative sampling. However, these did effectively remain exclosures from 1977 until the present, apart for the disturbance which probably occurred during 1997, because post-1997 people were excluded from these areas. However, it is not possible to ascertain to what extent the exclosures were disturbed during the upgrade and construction phase of the UCS and new path network.

The exclosure plots were subject to an interesting disturbance pattern during the sampling periods as follows:

- Before 1977: disturbance through trampling.
- 1977 to 1985: no disturbance for 8 years after the exclosures were erected.
- 1985 to 1997: no disturbance for a further 12 years.

Thus the fenced plots were protected for 20 years up to this point.

- 1997: disturbance when exclosures were removed during the major upgrade of the UCS.
- 1997 to 2005: no disturbance because the plots were in a restricted area for 8 years.
- 2005 to 2010: no disturbance for a further 5 years.

The plots were protected for another 13 years after 1997 but interrupted by an unknown degree of disturbance during this year. Figures 17 and 18 show the comparison between exclosure Plots 4e, 5e and 6e between 1980 and 2010. The exclosures and trampled paths can be seen in the 1980 images, whereas the 2010 images show the same areas after the exclosure fences were taken down. A marked recovery in the vegetation can be seen in the 2010 images subsequent to the area becoming protected (i.e. post 1997 upgraded).

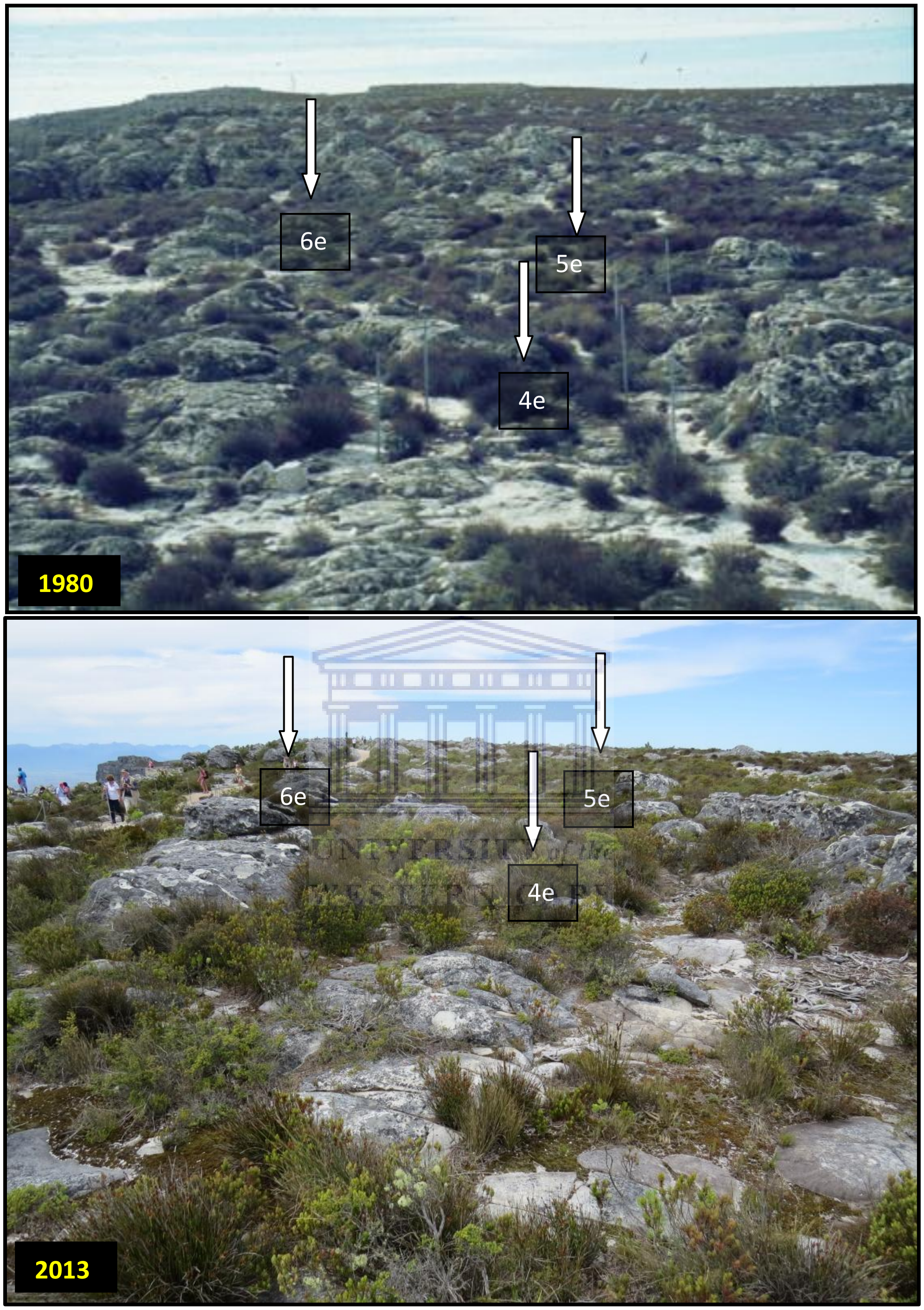

Figure 17. The three exclosure Plots 4e, 5e and 6e in 1980 (Moll 1980) and 2013. The informal path network is less evident in the 2013 photo but visible in the vicinity of Plot 4e in the 2013 image. The images were taken from slightly different perspective but still show regeneration of vegetation in 2013.

Figure 18. Close-up of exclosure Plot 6e in 1980 (Moll 1980) and 2013. Note the footpath running through the centre of the plot and along the left hand side in 1980 and the marked recovery in 2013. Although the exclosure plots were taken down during the 1997 upgrade, the erection of a barrier along the newly constructed path system ensure than the exclosure remained protected from trampling.

The twenty year period between 1977 and 1997 nonetheless allowed for trampling disturbance in the open plots. As previously mentioned all plots, except the furthest and least disturbed Plots 10, 11 and 12, effectively became exclosures following the 1997 upgrade as this became a restricted zone. Although Plots 10, 11 and 12 were never fenced off, they occur in a low impact area and are regarded as 'protected' by distance from the UCS. The remaining open plots (Plots 1, 2, 3, 4e, 5e, 6e, 7, 8 & 9) were subject to the following disturbance pattern:

- Before 1977: disturbance through trampling
- 1977 to 1997: disturbance through trampling
- 1997 to 2010: no disturbance after major upgrade. Area becomes restricted.

4.2. Ordination of plot data

A Nonmetric Multidimensional Scaling (NMDS) ordination comparing firstly, the 1977 and 2010 data sets (Figure 19) and secondly, all sampling periods (Figure 20) (highest fidelity species only - 24 species and 60 plots - including plots which were not surveyed due them being missing or lost due to construction activities), was carried out to determine degree of similarity between the sampling periods using the statistical software package R. I received help with this analysis from Jasper Slingsby and Emma Gray. When comparing the 1977 and 2010 the ordination produced a distinct general separation between the plots for each sampling period. Exceptions were Plot 5e and 9 in 2010, which was more similar to the 1977 plots, and Plot 5 of 1977, which was more similar to the 2010 plots. The general separation shows that the vegetation has changed markedly between 1977 and 2010. The ordination with the inclusion of all sampling periods did not produce any definitive groupings.

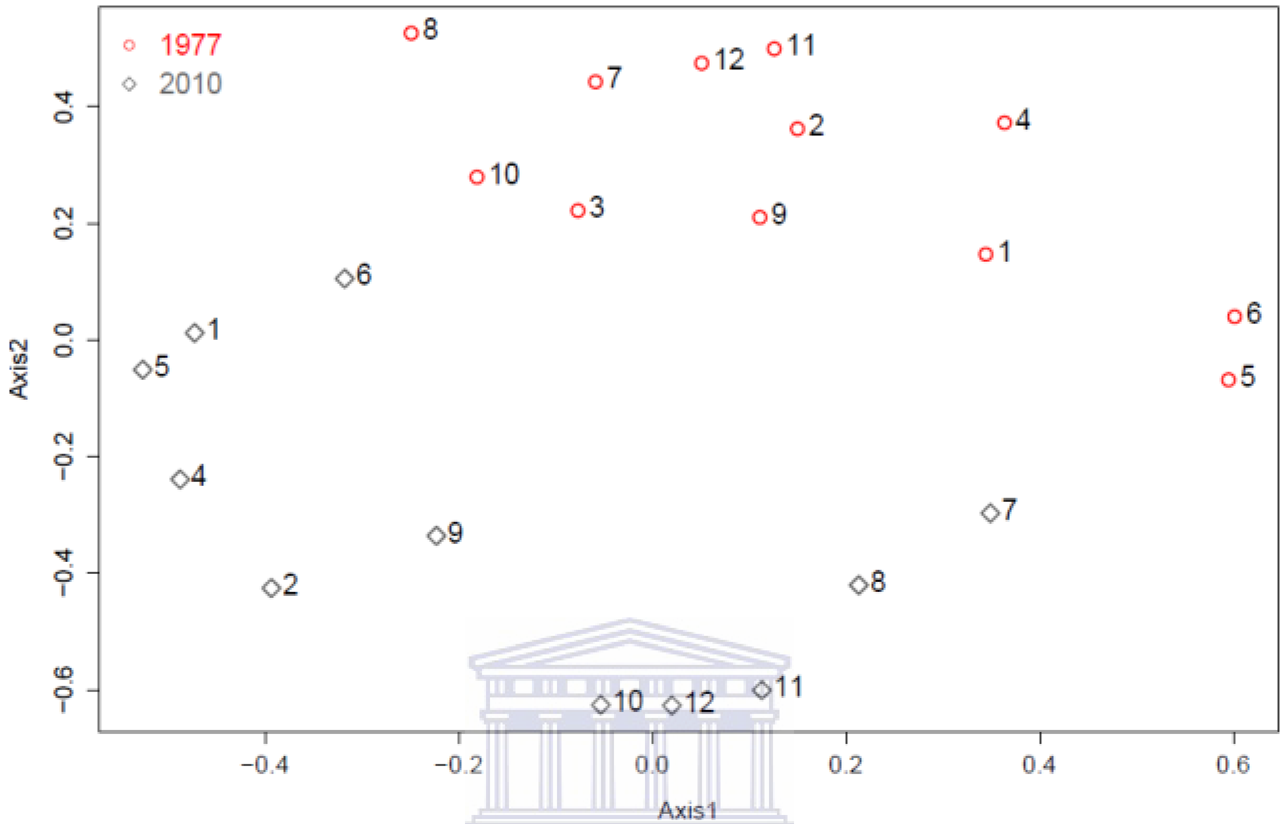

Figure 19. NMDS biplot of a Bray-Curtis dissimilarity matrix of plot data for sampling periods 1977 and 2010. Minimum stress for dimensionality = 0.22. R^2 for minimum stress configuration = 0.778. Plot 3 was not included in the 2010 data set since the plot was paved over during the 1997 upgrade.

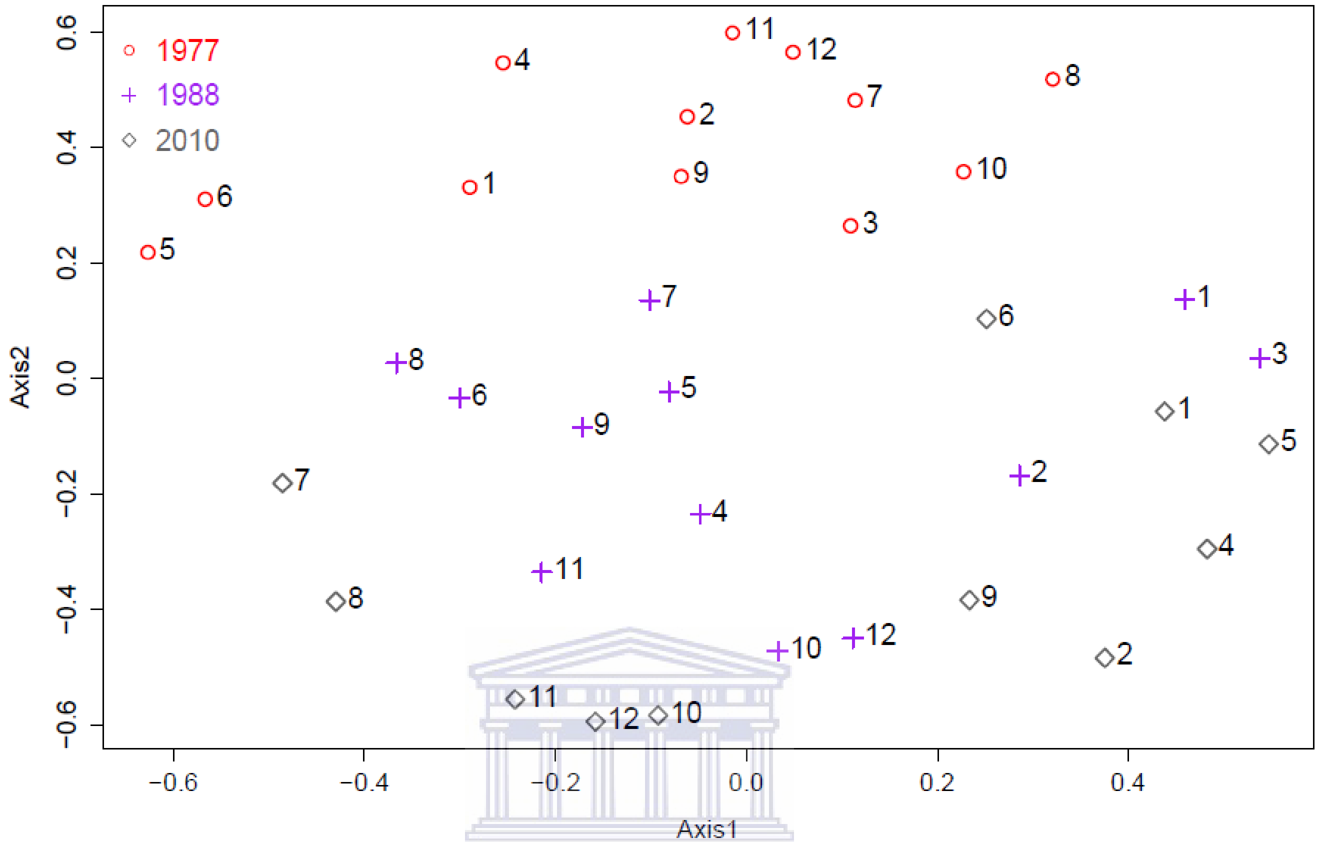

Figure 20. Multi-dimensional scaling ordination showing the degree of similarity between plot sampling periods of 1977, 1988, and 2010. Minimum stress for dimensionality = 0.278. R^2 for minimum stress configuration = 0.6198. Plot 2 was not included since the plot was only found towards the end of the study.

4.3. Change in communities

Two phytosociological tables for the two sampling periods (1977 & 2010) are presented in Tables 5 and 6 so that communities and subcommunities for each sampling period can be identified. Both tables are considered important since it is necessary to distinguish what have been the major changes. An all encompassing table of all data sets is presented in chronological order in Appendix A (1977, 1985, 1988, 2005 & 2010).

Plant communities were identified on the basis of their floristics in the 1977 and 2010 data sets. These communities then formed the basis from which to compare changes in community composition from both time periods. Community identification was recognized by grouping faithful species across relevés. The following communities were recognized:

1977: *Restio perplexus-Anthospermum aethiopicum* Community

The restioid *Restio perplexus* and shrub *Anthospermum aethiopicum* were present in all plots. *Restio perplexus* had the highest cover value of the two. In Plot 1 *Restio perplexus "could not be positively identified in some cases as the only evidence of its possible presence were roots with traces of stubble. It appeared to be particularly prone to damage from trampling"* (Coley 1977).

Additional faithful species in the community include *Pentaschistis curvifolia, Chrysitrix capensis, Ursinia nudicaulis, Cliffortia ruscifolia, Ehrharta ramosa* subsp*. aphylla* and *Elegia ebracteata*.

By 2010 this *Restio perplexus – Anthospermum aethiopicum* community had changed its composition, with *Cliffortia ruscifolia – Elegia ebracteata* becoming dominant. Thus a major shift in community composition had occurred. This is an important finding since it shows a shift from two active disturbance associated species, namely a soft, (slightly) trample tolerant restioid (*Restio perplexus*) and pioneer shrub (*Anthospermum aethiopicum*), to two post disturbance associated species; namely a brittle low disturbance linked restioid (*Elegia ebracteata*) and hardy shrub (*Cliffortia ruscifolia*).

2010: *Cliffortia ruscifolia-Elegia ebracteata* Community

This community must have resulted from the past disturbance regime due to trampling by tourists, which has allowed the long-lived pioneer *Cliffortia ruscifolia* to becoming locally dominant. The findings above show that, although unexpected, the species has recovered via resprouting, which explains the dominance in 2010.

Additional faithful species in the community include *Erica hispidula, Anthospermum aethiopicum*, *Thamnochortus nutans*, *Erica plukenetii*, *Ehrharta ramosa* subsp*. aphylla* and *Restio bifidus*.

An important aspect of community change is the variation in longevity of species and their response to disturbance patterns. Perennial species within the communities vary from several years (e.g. *Anthospermum aethiopicum, Lampranthus falciformis*) to several decades (e.g. *Elegia ebracteata, Restio bifidus*) or possibly centuries, which means, depending on the intensity of disturbance, that the longer lived components would be more or less static under a low disturbance regime or where rootstocks of resprouting species persist. This was certainly true for a number of plots where the restioids *Elegia ebracteata* and *Restio bifidus* persisted over the 33-year period due to resprouting. Long-lived perennial species are therefore important components for the long-term stability of communities, in particular resprouting species. They are therefore useful in their application for long-term monitoring and for determine the underlying disturbance regimes in fynbos ecosystems.

Short-lived pioneer species are also important indicators of change since they provide insight into the transitional state of the vegetation in relation to the management or disturbance

Table 5. Phytosociological table of Western Table showing the 1977 communities from plots surveyed by Coley (1977) and Emms (2010)

	1977 relevés												**2010 relevés**											
Species	**1**	**9**	**6**	**2**	**4**	**3**	**10**	**7**	**5**	**12**	**11**	**8**	**1**	**9**	**6**	**2**	**4**	**3**	**10**	**7**	**5**	**12**	**11**	**8**
Community 1: 1977																								
Restio perplexus	2	2	r	2	2	2	2	2	1	2	2	+	1		2	+								+
Anthospermum aethiopicum	+	+	+	r	+	+	+	1	+	+	+	1	1	+	1	1	+			1	1	+		+
Chrysitrix capensis	+	+	+	+	+	+	+	+	+	+	+	1									+			
Pentaschistis curvifolia	2	+	2	1	2	+	+	+	2	+	+						1			2	1			
Ursinia nudicaulis	+	2	+	+	+	1	2		+	2	2	+												2
Cliffortia ruscifolia	+	+	r	+		2	2	+	+	+		+	2	2	2	3	2		1	1	2	+	+	+
Ehrharta ramosa subsp. *aphylla*	1	1	+	1	+	1	+	1	+	+			2	1	1	2				2	2	r	1	
Elegia ebracteata	1	+	+	+	+	+	+	1	+			+	1	+	+	3	2		2	2	r	2	3	3
Subcommunity 1a: 1977																								
Crassula coccinea	+			2	3	2	1	2		2	2	2	1		r	+	+			r	+			r
Lampranthus falciformis		1				+	2	2		2	+	1	1	1	+	1	+		r		r			r
Subcommunity 1b: 1977																								
Hypochaeris radicata		1	1	1			+	+	2	+	+	1	1		1	+	1			r	1			
Disa bracteata		r	r		r			2	+	+	+		r							r	r			r
Thamnochortus nutans	+					1		r						+	+	1	r		1	+		1	1	+
Erica plukenetii	r	1	+	+	r	r		r					2	+	1	3	3			1	2	r		r
Restio bifidus									2	+	+			+					r	2	+	+	1	1
Euryops abrotanifolius					+		r	+	+	+	1			r							r	r		+
Pentaschistis tortuosa		+	2	+		+		r	2					r	+					+				
Penaea mucronata		r				+		r	r			r							+			+	r	
Erica ericoides						r	+	r			r			1		3								
Tritoniopsis unguiculatus							+	+				+			r		r		+			r	+	
Ehrharta setacea subsp. *setacea*																	1		r		r		+	
Hymenolepis parviflora													+		r					+				
Erica hispidula														2		2	+		2	+	r	3	2	1
Moss															2		2				2			
Number of species	**11**	**14**	**12**	**12**	**11**	**15**	**14**	**18**	**14**	**13**	**12**	**11**	**11**	**12**	**14**	**12**	**13**	**0**	**9**	**14**	**16**	**11**	**9**	**13**

Table 6. Phytosociological table of Western Table showing the 2010 communities from plots surveyed by Coley (1977) and Emms (2010)

	2010 relevés													1977 relevés											
Species	**7**	**5**	**9**	**4**	**6**	**8**	**1**	**12**	**10**	**11**	**6**	**2**	**3**	**7**	**5**	**9**	**4**	**6**	**8**	**1**	**12**	**10**	**11**	**2**	**3**
Community 1: 2010																									
Cliffortia ruscifolia	1	2	2	2	2	+	2	+	1	+	2	3		+	+	+		r	+	+	+	2		+	2
Elegia ebracteata	2	r	+	2	+	3	1	2	2	3	+	3		1	+	+	+	+	+	1		+		+	+
Erica hispidula	+	r	2	+		1		3	2	2		2													
Anthospermum aethiopicum	1	1	+	+	1	+	1	+			1	1		1	+	+	+	+	1	+	+	+	+	r	+
Thamnochortus nutans	+		+	r	+	+		1	1	1	+	1		r						+					1
Erica plukenetii	1	2	+	3	1	r	2	r			1	3		r		1	r	+		r				+	r
Ehrharta ramosa subsp. *aphylla*	2	2	1		1		2	r		1	1	2		1	+	1	+	+		1	+	+		1	1
Restio bifidus	2	+	+			1		+	r	1					2						+		+		
Subcommunity 2a: 2010																									
Lampranthus falciformis		r	1	+	+	r	1		r		+	1		2		1			1		2	2	+		+
Crassula coccinea	r	+		+	r	r	1				r	+		2			3		2	+	2	1	2	2	2
Subcommunity 2b: 2010																									
Tritoniopsis unguiculatus				r	r			r	+	+	r			+					+			+			
Ehrharta setacea subsp. *setacea*		r		1					r	+															
Hypochaeris radicata	r	1		1	1		1				1	+		+	2	1		1	1		+	+	+	1	
Euryops abrotanifolius		r	r			+		r						+	+		+				+	r	1		
Disa bracteata	r	r				r	r							2	+	r	r	r			+		+		
Restio perplexus					2	+	1				2	+		2	1	2	2	r	+	2	2	2	2	2	2
Hymenolepis parviflora	+				r		+				r														
Pentaschistis tortuosa	+		r		+						+			r	2	+		2						+	+
Penaea mucronata								+	+	r				r	r	r			r						+
Pentaschistis curvifolia	2	1		1										+	2	+	2	2		2	+	+	+	1	+
Ursinia nudicaulis						2									+	2	+	+	+	+	2	2	2	+	1
Erica ericoides			1									3		r								+	r		r
Chrysithrix capensis		+												+	+	+	+	+	1	+	+	+	+	+	+
Moss		2		2	2						2														
Number of species	**14**	**16**	**12**		**14**	**13**	**11**	**11**	**9**	**9**	**14**	**12**	**0**	**18**	**14**	**14**	**11**	**12**	**11**	**11**	**13**	**14**	**12**	**12**	**15**

pattern. A combination of damaged long-lived resprouters with increased cover in short-lived pioneer species would indicate past high disturbance, whereas increased cover of long-lived resprouters and decrease in pioneer species is indicative of recovery under a prolonged low disturbance pattern.

4.3.1. Subcommunities

In 1977 two subcommunities were recognized, and two were also recognized in 2010. The subcommunities were recognized on the basis of shared species, although with different key species, across plots. These subcommunities fall outside the main communities.

1977: The first subcommunity in 1977 comprises *Disa bracteata* and *Hypochaeris radicata,* and the second subcommunity comprises *Crassula coccinea* and *Lampranthus falciformis*. This second association, which is found in rock crevices and on skeletal soils i.e. within a separate sub-habitat, was also present as a subcommunity in 2010. For both periods the exotic weed *Hypochaeris radicata* is closely affiliated to the *Crassula coccinea* and *Lampranthus falciformis* Subcommunity, however, *H. radicata* formed a distinct subcommunity with *Disa bracteata* in 1977. The *Crassula coccinea* and *Lampranthus falciformis* Subcommunity was present as a markedly lower cover association in 2010. It is concluded that this is due to the increased restioid and shrub cover in 2010, which has reduced the amount of available habitat open space for the two species.

In 2010 the second subcommunity comprises the geophyte *Tritoniopsis unguiculatus* and the grass *Ehrharta setacea* subsp. *setacea.* This is a very 'loose' association which does not seem to indicate any important ecological patterns that I was able to discern.

4.4. Changes in species diversity

A paired sample t-test between plots sampled in 1977 and 2010, excluding the plots missing in 2010 (Plot 3) showed that there was no significant difference in species numbers between the two sampling periods (t-stat = 0.923077; t Critical one-tail = 1.833113; t Critical two-tail = 2.26157; P (T<=t) two-tail). This is not surprising considering that the long fire interval (80 – 90 years) has, in all likelihood, selected out the obligate, fire-maintained species. Certainly in the event of a fire on the Western Table there would be increased coexistence (Kruger, 1983, Cowling 1987; in Cowling et al. 1992) since fire leads to differential recruitment (Van Wilgen & Kruger 1981; in Cowling et al. 1992), however, it should also be noted that species richness values for mature fynbos (Cowling et al. 1992) would not necessarily be markedly lower than for post-fire fynbos (Specht 1988; in Cowling et al. 1992).

Schwilk et al. (1997) showed that in fynbos systems subjected to different fire disturbance cycles, the species diversity patterns contradicted the intermediate disturbance hypothesis (IDH). In their study sites species diversity was highest in the least fire-disturbed areas (40 years between fires) and lowest at sites of moderate fire disturbance (15 to 26 years) and high disturbance (four to six years). Interestingly the species diversity patterns for all sampled plots in 1977 and 2010 (for species having a BB cover value >r) did not show a significant difference.

4.5. Major trends in selected species

The major trends between 1977 and 2010 were regarded as the most important in terms of assessing the long-term change through time since it is crucial to determine how the vegetation has responded following the 1997 upgrade. Species change is an important indicator of the ecological state of the vegetation after protection from trampling. When comparing plots from 1977 to 2010 (Table 3), any major loss or gain in species occurrence or cover abundance is likely to be related to disturbance regime. Species that were present in 1977 would have been resilient if present at high cover values, whereas those present in 2010 are likely to be at a more 'climax' stage or they are resprouters which have regenerated in the absence of disturbance. Similarly species that were absent in 1977 were most likely highly sensitive to trampling, whereas those absent in 2010 are more likely to be short-lived and characteristic of high disturbance or have gone locally extinct due to lack of disturbance. The major trends are discussed according to change in species fidelity and cover. The major trends relate to those species that underwent the most discernible changes, which is why they are used as key indicators. The findings of the major species trends are discussed below:

Restio perplexus: steady decline in both fidelity and overall cover from 1977 to 2010 (100% fidelity in 1977 to 30% in 2010). The species was not recorded in 1988 in Plot 1, yet occurred in all remaining sampling periods for this plot – most probably this absence was due to sampling error. This soft-stemmed, tufted restioid, declined most notably after the 1997 upgrade – when all plots effectively became exclosures, inferring that the species requires regular disturbance. In this instance the disturbance regime has been trampling and not the ecological norm of fire.

Chrysitrix capensis: a fairly rapid and steady decline occurred after 1985 (fidelity: 1977 = 100%; 1985 = 90%; 1988 = 30%; 2005 [minus Plots 1 & 2] = 20%; 2010 [minus Plot 1] = 10%). In 1985 Plots 4e; 6e and 7 increased from + cover values to 1. The cover increase in Plots 4e and 6e was expected, considering the plots were exclosures at the time and in view of the species being a resprouter. Thus protection from trampling allowed for regeneration and increase in cover. Increase in Plot 7 seems to be somewhat of an anomaly considering the species is not likely to undergo cover increase when subject to trampling disturbance. The pattern in Plot 7 is unexplained but may relate to aspects such as vegetative growth spurts or slight changes in tourist traffic.

Pentaschistis curvifolia: high fidelity and cover values were maintained from 1977 (12 plots surveyed) to 1985 (11 plots surveyed) (90% & 100% fidelity respectively for both sampling periods). The species was almost certainly incorrectly identified in 1988 since the fidelity dropped to 10% with low cover (i.e. Plot 7 = +). In 2005, of the 10 plots surveyed, the species was present in 90% of the plots with considerably lower cover values, whereas the fidelity had dropped to 30% in 2010, having corresponding cover values for Plots 4, 5 and 7 for both sampling periods. It is not understood why the species cover and fidelity has fluctuated in this way. It may be that there is a lag recovery response following periods of disturbance, whereby disturbance causes a temporary increase in fidelity and cover within the first few years and then declines under a low disturbance regime.

Ursinia nudicaulis: the species declined markedly, from 90% fidelity in 1977 to 10% in 2010. The species is a pioneer, which explains why it has disappeared in the protected plots.

Cliffortia ruscifolia: increased in cover in several plots between 1977 and 2010. Most notably, in 2010, the species increased from + to 2 in Plots 1, 5 and 9, from r to 2 in Plot 6, from + to 1 in Plot 7, and from no cover to + in Plot 8. The species declined in cover from 2 to 1 in Plot 10. The marked increase can be attributed to several possibilities, of which the two most likely causes are recovery of trampled individuals (i.e. resprouting) and colonization. The species thrives in disturbed areas and is also long-lived, so persistent.

Elegia ebracteata: a noticeable increase in cover occurred from 1977 to 2010, in particular within the three least disturbed plots (Plots 10, 11 & 12). Initial cover increase occurred by 1985 within the three exclosures. These plots underwent fluctuating changes thereafter until 2010. Following the 1997 upgrade the species reached the highest cover values in Plots 8; 11 and 12, inferring sensitivity to trampling and ability to recover via resprouting. The species is a common reseeder (killed by fire) on Table Mountain and grows on shallow soils over bedrock and may also be associated with slight seasonal seepage (Linder 2011). It was present in 25% of plots 1977 and in 100% of plots in 2010 and increased in cover by at least one BB cover value in six of the plots sampled in 2010. Interestingly this increase did not only occur in the disturbed plots but also in the least disturbed plots (Plots 10, 11 & 12) meaning the species does not die out in the absence of fire.

Careful analysis of the photographic records shows that even these least disturbed plots (10, 11 & 12) were partially trampled in the past since there are clearly defined paths across the plots (Section 4.6). The paths had disappeared by 2010. It is thus concluded that *Elegia ebracteata* is either capable of resprouting after non-fire disturbance and/or of reseeding in the absence of fire but under a physical disturbance regime. The recovery of the species in the three exclosure plots (4e, 5e & 6e) suggests that resprouting is the more likely strategy of recovery under a non-fire disturbance pattern. Thus although fire is regarded as the main stimulus for survival of the species through seed regeneration, this indicates that the species does not become locally extinct under a low frequency fire cycle, provided there is physical disturbance.

Crassula coccinea: the highest cover values we recorded in the initial 1977 high intensity areas, including Plots 2 and 3, which may be due to trampling-induced gap availability (i.e. low vegetation cover) – the habitat in which the rock-dwelling species usually thrives. The species also increased considerably in exclosure Plot 5e by 1985 (1977 = absent; 1985 = 2). The high cover during the initial sampling was not expected as the species is considered to be sensitive to trampling. It is possible; however, that following an initial trampling effect (before the informal path was developed through the plots), gaps were created on either side of the informal path, and that as the informal path was used, an initial opportunistic growth-spurt resulted in cover increase for that period. Once the informal path became more defined, less pressure was placed on the off-path vegetation, which enabled other species to recover and out-compete *Crassula coccinea*. This hypothesis would need to be tested.

In addition to Plots 2 and 3, high cover was recorded in the initial 1977 sampling in one of the three least disturbed plots (Plot 11); however, by 1988 the species had disappeared from Plots 10, 11 and 12 and remained absent at the 2010 sampling period. Observations in 2005 and 2010 were that the species was present as seedlings or low (several centimetres high) individuals. The species occurs most often in rock cracks and as a seedling pioneer in shallow soils. Further the species is brittle and sensitive to trampling. The ability of the species to colonize open, shallow gaps and rock crevices; however, means the patterns of cover are erratic, since they may succumb to drought, or at least stunting due to lack of deep sands.

Leaf and stem succulence allows for short-term drought tolerance and therefore a degree of resilience over less woody species. The species does not appear to rely on vegetative reproduction strategy employed by some succulent species; instead it appears that seed is the preferred recruitment strategy. In summary the general decline and disappearance of the *Crassula coccinea* through time is thought to be evidence of lack of regular disturbance patterns and gap creation, which would otherwise lead to a higher, albeit, temporary increase-decrease in cover pattern.

Erica plukenetii: this brittle species is sensitive to trampling disturbance and was thus present at low cover values in 1977, with fidelity of 60%. Fidelity increase to 80% by 2010 and the species increased in cover markedly in Plots 1 (r to 2), 4 (r to 3), 6 (+ to 1), 5 (no cover to 2) and 7 (r to 1). The species decreased for the same period in Plot 9 (2 to 1). The species is usually a reseeder but is capable of resprouting, meaning the species may have employed both strategies, but regardless, the increase in cover is undoubtedly a reaction to the lowered trampling pressure.

4.5.1. Additional trends: species presence/absence

In 1977 *Thamnochortus nutans* was trampled, damaged and present at relatively low cover. The species then underwent a marked increased in cover by 2010. The photographic records from

1977 and 2010 (Section 4.6) show the same individuals present after more than 30 years. The species is able to persist in this way due to its resprouting life strategy. Coley noted that the species was under threat in the study area because of trampling. The species was also highlighted in the interim report on the threatened and endangered plant species on Table Mountain (MCSA, 1976) reported that *"Degradation of the fragile summit vegetation though trampling and eutrophication could pose a threat to the species* Thamnochortus nutans*".*

Interestingly the species was not recorded in the three least disturbed plots (Plots 10, 11 & 12) in 1977 but was present in 2010 at a cover value of 1 for all three plots. Its reappearance in the remaining plots was expected since the species would not have been identifiable in the higher impact areas, since only the trampled bases were visible. After protection it would have resprouted and would have then been easily identifiable. This was not the case for Plots 10, 11 and 12, which were deliberately positioned in an area of minimal disturbance. The appearance of the species in the latter three plots was, however, not expected, but after interrogating the photographic records there is a potentially contrary finding for Plot 11.

From the photographic evidence it seems likely that *Restio perplexus* was mistaken for *Elegia ebracteata* in Plot 11 in 1977; since there is no evidence of the former species, which is a tangled, soft-stemmed species. Instead the photographic record shows a typical upright, straight, hard-stemmed restioid. Since *Restio perplexus* was recorded at similar cover values in 1977 as *Elegia bracteata* in 2010, and since *Restio perplexus* is not visible from the photographic records in 1977 and the same individuals are clearly visible in the photographs during both sampling periods, it is concluded that it (*Restio perplexus*) was most probably mistaken for *Elegia bracteata*. It is not possible to absolutely verify this since the photographs do not provide a sufficient level of resolution to accurately identify species.

The reseeding restioid *Restio bifidus* was present in 25% of plots in 1977 and present in 70% of plots in 2010. This species is drought sensitive and dies out after long summers in the less permanently wet places on the Upper Table (Linder, pers. comm. 2012). Constant summer precipitation and fog are thus thought to have enabled the persistence of the species, which probably has the same type of reaction to no-fire disturbance regime as *Elegia ebracteata*. The increase in cover and fidelity is therefore most likely due to recover from physical disturbance such as trampling and its ability to persist for long periods; provided there is a constant supply of moisture relief over the summer periods.

Anthospermum aethiopicum: no major change occurred from 1977 to 2010 in terms of fidelity and cover abundance, apart from an increase in cover in 1985 (Plots 1, 6e, 7, 8, 9 & 10) and 1988 (Plot 7 = 2). It seems unlikely that this species would have occupied such a large surface area since my observations were that it reaches a high cover within disturbed patches of vegetation on the Western Table. Further the species is outcompeted, or displaced, by more aggressive, larger-growing species. It is more likely that the species did not reach the high cover values in 1985 (e.g. Plot 6e = 2, Plot 7 = 2 & Plot 8 = 2) and 1988 (Plot 7 = 2) and that these were overestimates on behalf of the fieldworker (Aubin). It is plausible (although unlikely) that these patterns were the result of the rigorously debated intermediate disturbance hypothesis, owing to the position of Plots 6e, 7 and 8 in the area of medium disturbance (trampling) pressure. In the least disturbed plots the species was either consistently present - at low cover values across the entire sampling period - or otherwise absent/or present at low cover values with fluctuating trends. This pattern is expected for a pioneer species occurring in mature, low disturbance communities.

***Ehrharta ramosa* subsp*. ramosa*:** no change in fidelity occurred between 1977 (80%) and 2010 (80%). The species underwent a slight increase in cover in 2010, notably Plots 1, 5, 6, 7 and 11. It is thought that this is due it's persistence following the initial trampling disturbance and lack of completion by perennial shrubs and restioids. A fire event would most probably allow for recolonisation of shrubs and restioids since seed set of such species would create competition between grasses.

Hypochaeris radicata: is an exotic weed, which thrives in disturbed open patches. The species was present in 75% of plots in 1977, when disturbance was at a high. Interestingly the species was present in the plots of least disturbance (10, 11 & 12) in 1977 and absent in the five least-disturbed plots (8, 9, 10, 11 & 12) in 2010. Since the species only occurs in open patches, this can be attributed to the increased cover and shade, as the paths across these plots have been re-colonised.

Conclusions

Restio perplexus is deemed to be declining in the study area due to lack of fire needed to stimulate regeneration of this reseeding species. This may be the general trend on the Western Table.

Chrysitrix capensis is deemed to be declining in the study area as a result of lack of fire. It is thought that the species is an obligate fire reseeder. This may be the general trend on the Western Table.

Ursinia nudicaulis is declining in the study area due to lack of disturbance.

Cliffortia ruscifolia has increased in the study area but this is merely a sign of recovery and colonization following the protection from trampling. The species may become more dominant over time now that the disturbance regime is very low. Increased cover would be a result of increased cover of existing individuals, which are long-lived. The increase in cover would be marginal though since strong winds and shallow soils would restrict the height of the species.

Anthospermum aethiopicum is declining in the study area indicating the recovery of the vegetation. This may be the general trend on the Western Table but would not be of concern for the species since it is a pioneer that would not undergo local extinction on the Mountain.

Erica plukenetii is increasing in cover on the Mountain due to reduced trampling pressure. The species is usually a reseeder but is capable of resprouting. It is predicted that fire would lead to an increase in population of the species since it was observed that many individuals have numerous dead branches and these are with numerous senescent individuals currently.

Elegia ebracteata has increased markedly in both cover and fidelity in the study area and is not under threat due to absence of fire, even though the species is a reseeder. The results indicate that the species is capable of resprouting under a non-fire disturbance regime. In this case the disturbance was trampling. The same pattern of increased cover and fidelity over the same time period was recorded for the reseeder *Restio bifidus.* Constant moisture supply from the mist precipitation is an important variable that has prevented the species from dying out from drought over this prolonged period (80 to 90 years) without fire.

4.6. Vegetation change from transition matrix and cover-estimation applied to plot photographs

The results of the transition matrix are presented below. Appendix F lists the percentage cover for each of the counted and estimated categories and provides the grid overlay and category count for each plot for 1977, 1988 and 2010. The transition matrix data is regarded as more accurate than the rapid estimation approach and has therefore been used as the benchmark assessment. The cover estimations are discussed to a lesser degree. It is important to note that the photographs provide a different estimation perspective since the plots are viewed from an aerial perspective compared to standing within the plot during the field survey:

Plot 1

Vegetation cover increased steadily from 1977 to 2010. In 1977 and 1988 the vegetation is very sparse and low due to the trampling impact (Figure 21). Most notable is the increase in shrubs, restioids and grasses among the rock cracks and almost complete colonization of Moss in the open sandy patches in 2010. The increase was marginal for restioids (1977 = 2%, 1988 = 3%, 2010 = 4%) and more pronounced for ericoids (1977 = 4%, 1988 = 10%, 2010 = 18%) (Figure 22). Importantly, Moss increased from no cover in 1977 and 1988 to 15% cover in 2010. The re-colonization of Moss establishes that the species is a key indicator of disturbance; in this instance it shows that the cordoned off plot following the 1997 upgrade, and protection from trampling pressure, enabled the marked recovery trend. A consequence of the Moss regeneration was a large decrease in sand cover in 2010 (1977 = 30%, 1988 = 24%, 2010 = 1%) since undisturbed sand is the preferred habitat for Moss growth, however moss stands open patches of Moss are not the norm in the study area. These reflect past disturbance and are therefore not considered to be the climax vegetation state.

Litter and free-standing dead material underwent a cover increase analogous to Moss, as the vegetation regenerated in the 2010 sample period (1977 = 1%, 1988 = 0%, 2010 = 10%). This can be attributed to natural senescence over the 13 years of protection form trampling. Rock cover did not change markedly since a large proportion of the rock cover is solid and bare, lacking cracks and sandy paths required for the establishment of plant growth. This is evident from the photographs. In addition to increased vegetation cover, the plot photographs show a structural change, with a noticeable height increase in 2010.

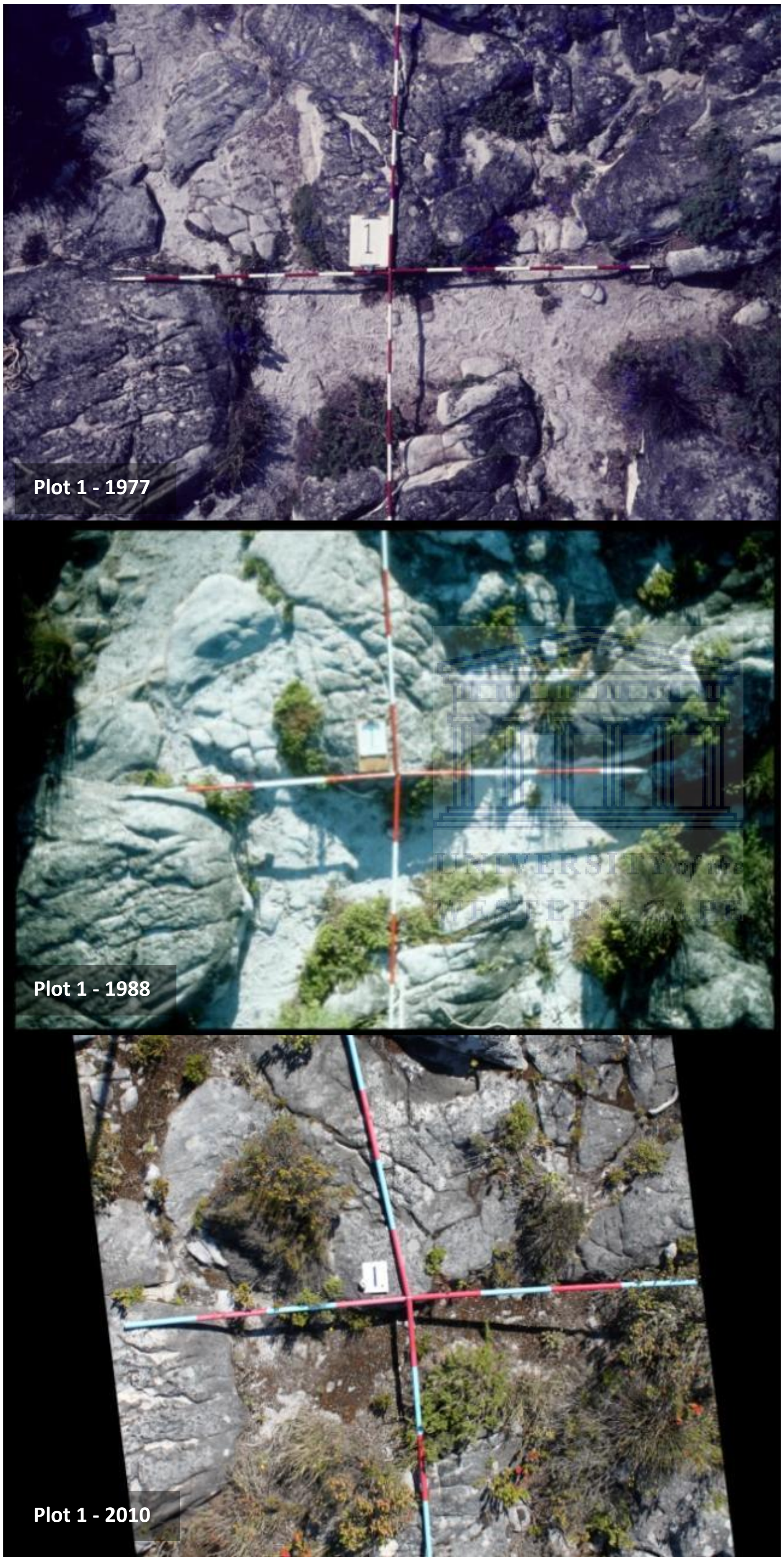

Figure 21. Photographic time series of Plot 1 recorded in 1977 (Coley), 1988 (van Coller & Kerbelker) and 2010. There comparison shows a marked increase in cover in the 2010 image. Notable changes in 2010 are increase in mosses over the previously bare sand and increase in shrubs and restioids.

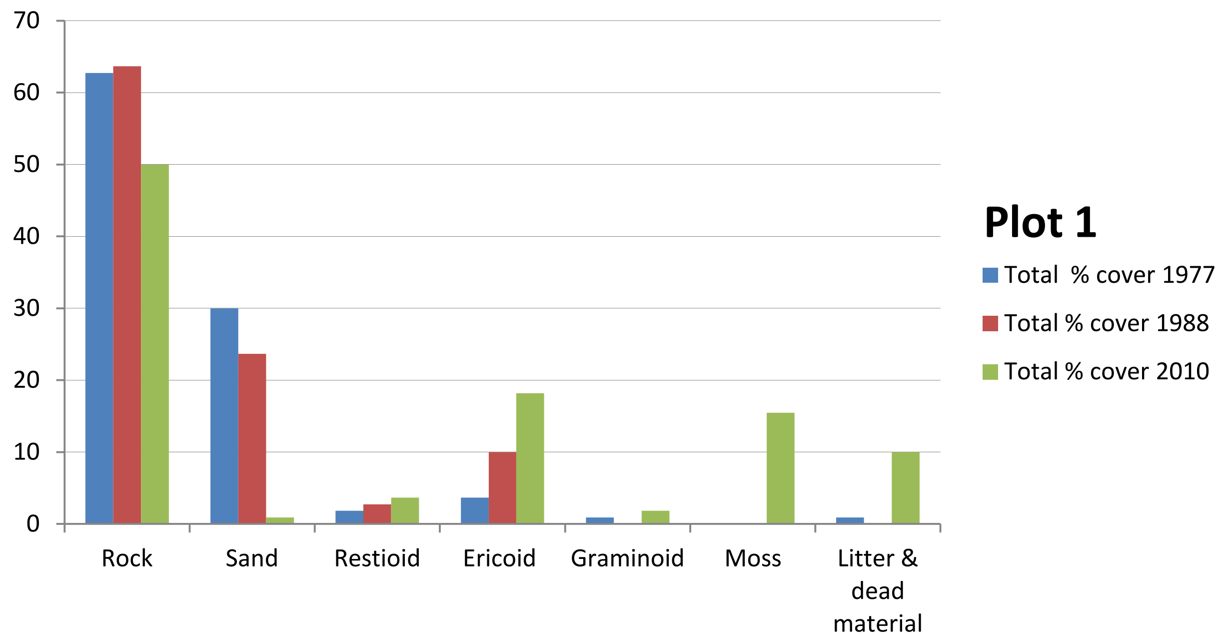

Figure 22. Total cover recorded from a transition matrix cell overlay in Plot 1 for the various broad habitat categories in 1977, 1988 and 2010.

Plot 4e

The plot image from 1977 shows almost no vegetation cover apart from a few restioids and clearly visible individual of *Ursinia nudicaulis*. Most evident in the 1988 image is the flush in restiod growth. In 2010 the recovery of shrubs, restioids and moss can be seen. The *moss* species has colonized the exposed, sandy patches. A portion the old path system is still visible in 2010 (Figure 23).

The most noticeable trend occurred in the restioid group, which underwent an initial spike in growth in 1988 followed by a marked decrease in cover in 2010 (1977 = 4%, 1988, 2010 = 8%) (Figure 24). The increase in cover in 1988 was due to the exclosure plot, which protected the area from trampling. The decrease in restioid cover can be explained by natural senescence, since the plot was effectively an exclosure from 1977 to 2010. Restioids tend to accumulate free-standing dead material as time increase between fire or disturbance intervals (personal observation).

Ericoid and moss cover both increased with time. Ericoids were present at each sample period (1977 = 1%, 1988 = 7 %, 2010 = 25%) whereas moss only appeared after the exclosure was erected (1977 = 0%, 1988 = 1%, 2010 = 5%). Litter and dead material was evident in 1977 as a result of trampling damage. Cover then decreased in 1988 and accumulated in 2010. As mentioned before the exclosure plots (Plots 4e, 5e & 6e) were effectively protected from 1977 to 2010 since the exclosure fences were taken down at the same time as Plots 1, 2, 3, 4e, 5e, 6e, 7, 8 and 9 became protected during the 1997 upgrade. This explains why the dead material initial deceased from 1977 to 1988 and then increased in 2010 since the initial recovery period between 1977 and 1988 resulted in an initial flush of new growth which would have a low accumulation of litter and free-standing dead material. The highest cover of litter and dead material recorded in 2010 was as a result of natural senescence. Lastly, the steady decrease in rock (1977 = 53%, 1988 = 36 %, 2010 = 22%) and to a lesser degree sand cover (1977 = 25%, 1988 = 6 %, 2010 = 5%) was due to increased vegetation cover.

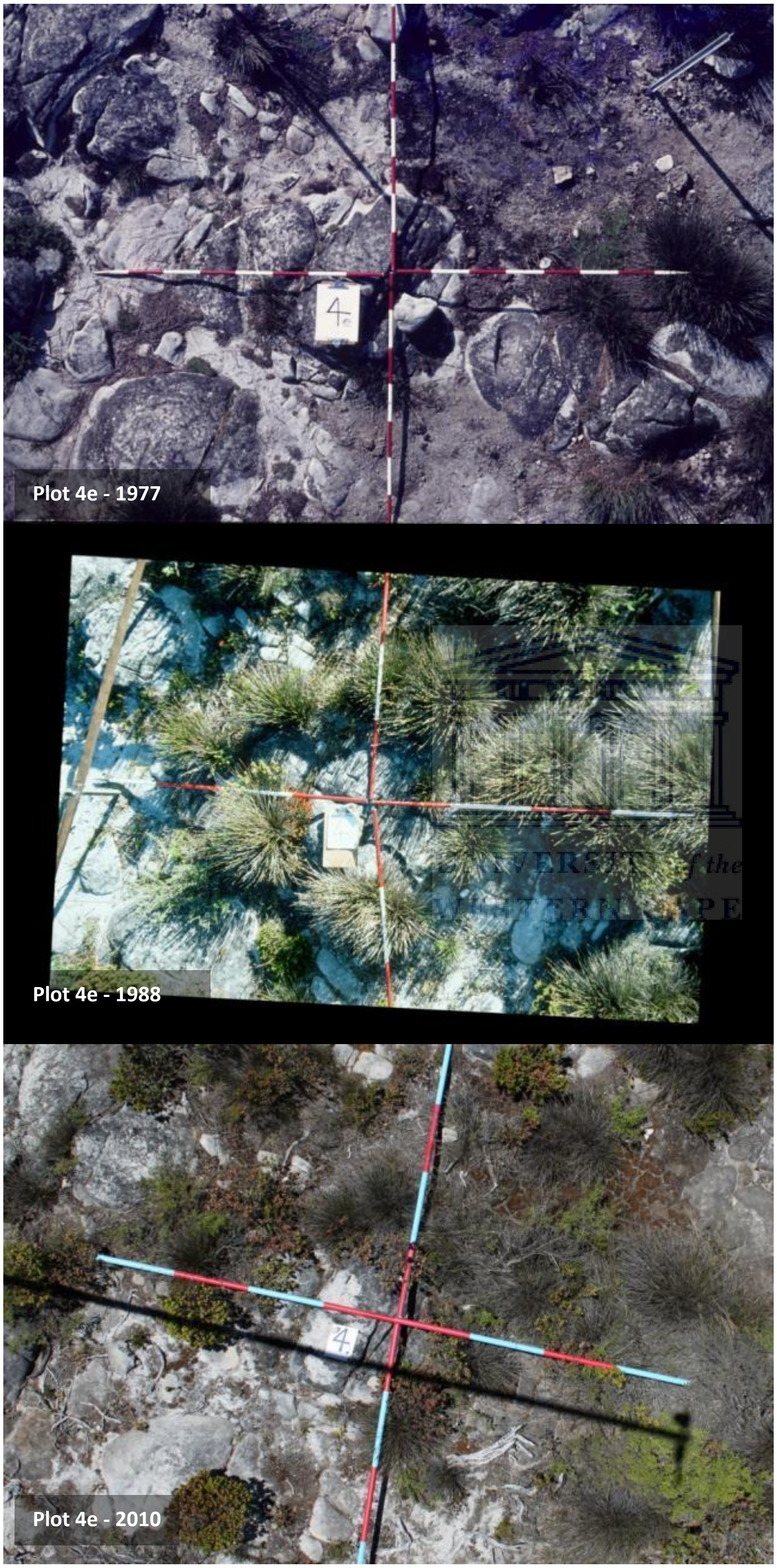

Figure 23. Photographic time series of Plot 4e recorded in 1977 (Coley), 1988 (van Coller & Kerbelker) and 2010. The exclusion plot shows a marked increase in restioids in 1988 due to protection from trampling. By 2010 an additional shrub component emerges and dead litter has accumulated.

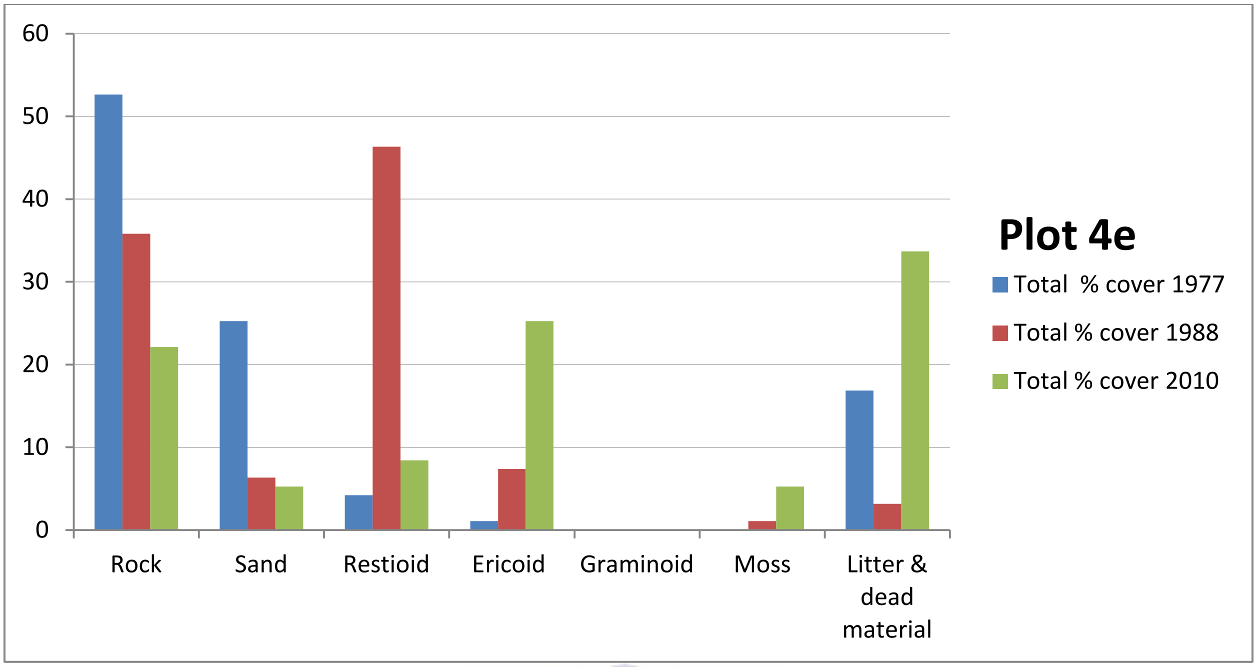

Figure 24. Total cover recorded from a transition matrix cell overlay in Plot 4 for the various broad habitat categories in 1977, 1988 and 2010.

Plot 5e

Plot 5e underwent a major change in structural composition over the 33-year monitoring period. In 1977 and 1988 restioids are dominant, whereas in 2010 the plot is dominated by ericoids and small proportion of moss (Figure 25). The most noticeable shift in cover occurred in the restioids, which increased from 1977 to 1988 and dropped to almost no cover constant levels in 2010 (1977 = 60%, 1988 = 70 %, 2010 = 4%) (Figure 26). This is a similar pattern to Plot 4e, however restioid cover was already high (60%) before the plot became an exclosure compared to Plot 4e that was heavily trampled before the exclosure was erected. The trend after 1988; that is, a considerable decrease in restioid cover, is attributed to natural senescence, which is comparable to the trend in Plot 4e.

Ericoids were not present in 1977, which can be attributed to the high trampling intensity and susceptibility of this brittle growth form category. The group steadily recovered until 2010 where the highest cover was recorded (1977 = 0%, 1988 = 4 %, 2010 = 20%). The emergence of Moss in 2010 (4% cover), which was not present in the previous sampling periods, is due to senescence of restioids between 1988 and 2010 since the gap created over this period was previously covered in restioids. Free-standing dead material is clearly evident in the 2010 plot image; a natural senescence trend.

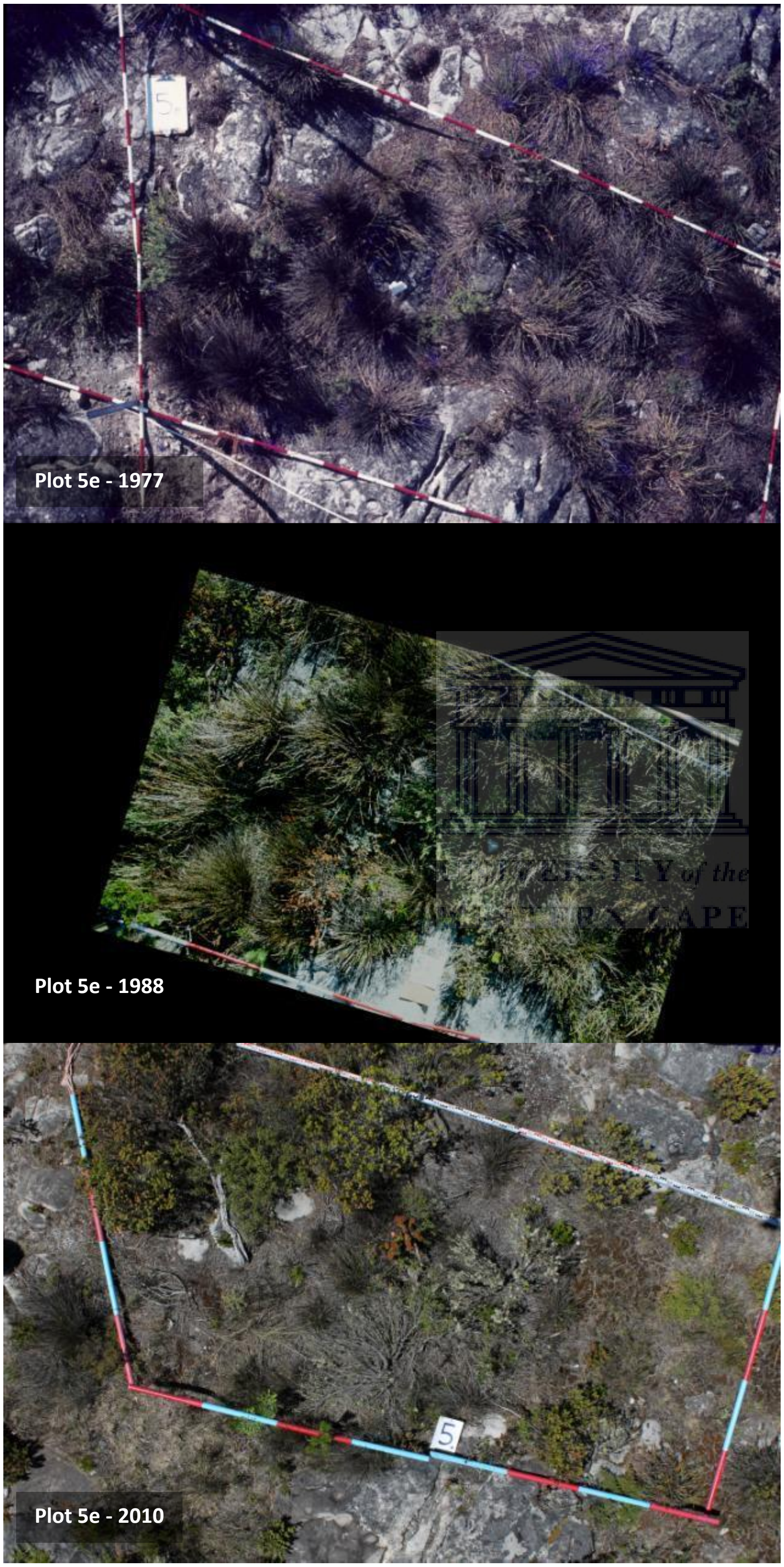

Figure 25. Photographic time series of Plot 5e recorded in 1977 (Coley), 1988 (van Coller & Kerbelker) and 2010. The plot was dominated by restioids in 1977 and 1988. Ericoid cover increased in 2010 along with an accumulation of free-standing dead material due to senescent restioids.

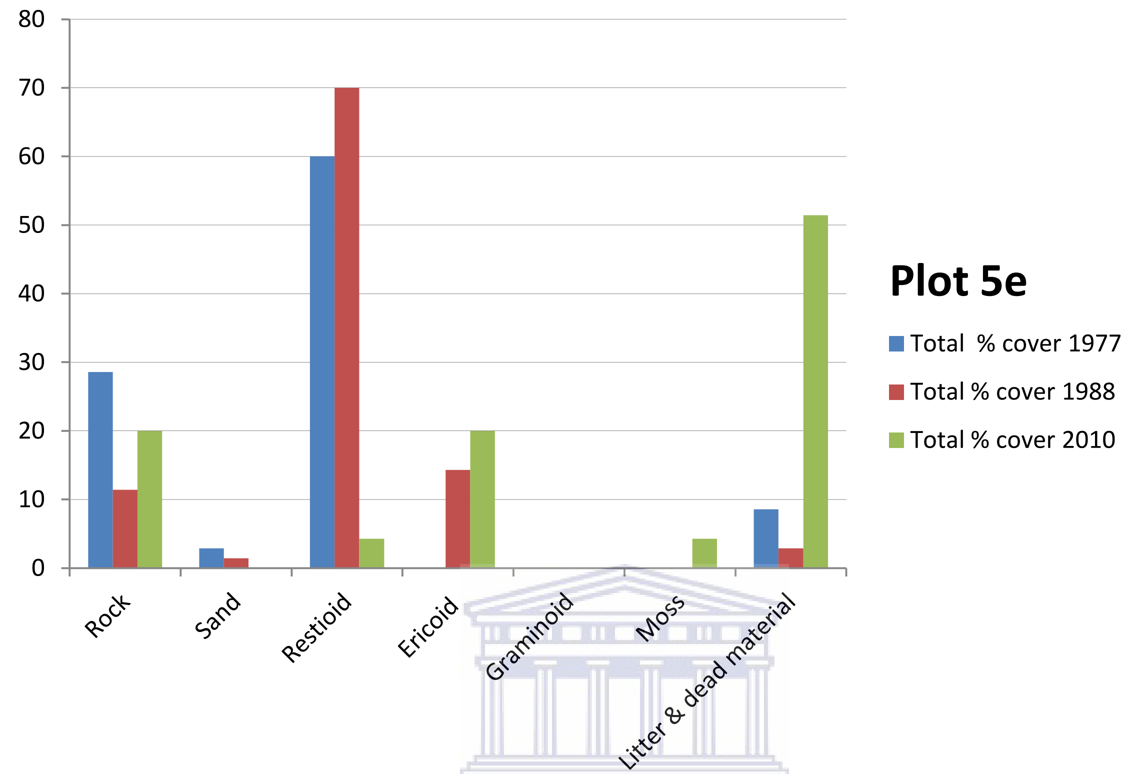

Figure 26. Total cover recorded from a transition matrix cell overlay in Plot 5e for the various broad habitat categories in 1977, 1988 and 2010.

Plot 6e

A similar shift in cover change to Plot 4e and 5e occurred in Plot 6e. Restioid increased in cover from 1977 to 1988, followed by a slight decrease in 2010 (1977 = 4%, 1988 = 25 %, 2010 = 17%) (Figures 27 & 28). Again, as with Plots 4e and 5e this is attributed to natural senescence of the growth form. Plot 6e had almost no vegetation cover present in 1977 since the path was located in one of the informal paths. The 1988 and 2010 images show major change, with a greater variety of growth forms evident, including shrubs, restioids, grasses (2010) and moss.

Restio perplexus is clearly visible in this plot and appears to have resprouted from the stumps of individuals evident in the 1977 image.

Ericoid cover increased gradually from 1977 to 1988 and then increased sharply from 1988 to 2010 (1977 = 2%, 1988 = 7 %, 2010 = 23%). Since the plot was heavily impacted in 1977; having only 6% total vegetation cover, moss was not present. The growth form emerged in 1988 (11% cover) and persisted, with a slight decrease until 2010 (6% cover). The patches of sandy habitat colonized by Moss in 1988 were replaced with ericoids in 2010. Litter and free-standing dead material was low in 1977 and 1988 but increased substantially in 2010 (1977 = 5%, 1988 = 2 %, 2010 = 32%). Rock and sand cover decreased over time as the overall vegetation regenerated and dead material accumulated (Rock: 1977 = 43%, 1988 = 40 %, 2010 = 17%; Sand: 1977 = 47%, 1988 = 15 %, 2010 = 2%).

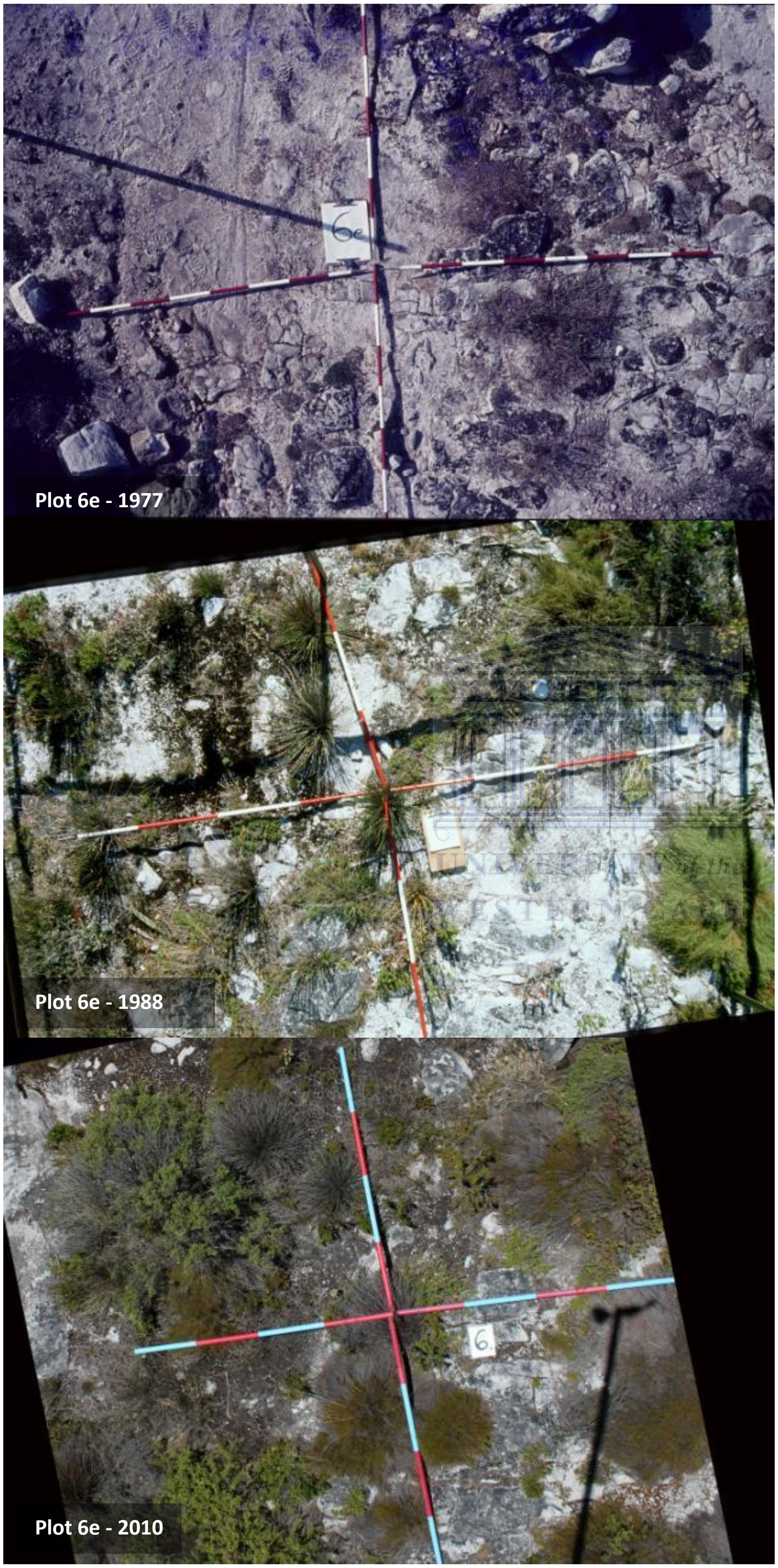

Figure 27. Photographic time series of Plot 6e recorded in 1977 (Coley), 1988 (van Coller & Kerbelker) and 2010. Note the heavily trampled plot in 1977 and how the vegetation has recovered after becoming an exclosure in the 1988 image. There was a substantial increase in ericoid growth between 1988 and 2010, which is coupled with and accumulation of dead material in 2010.

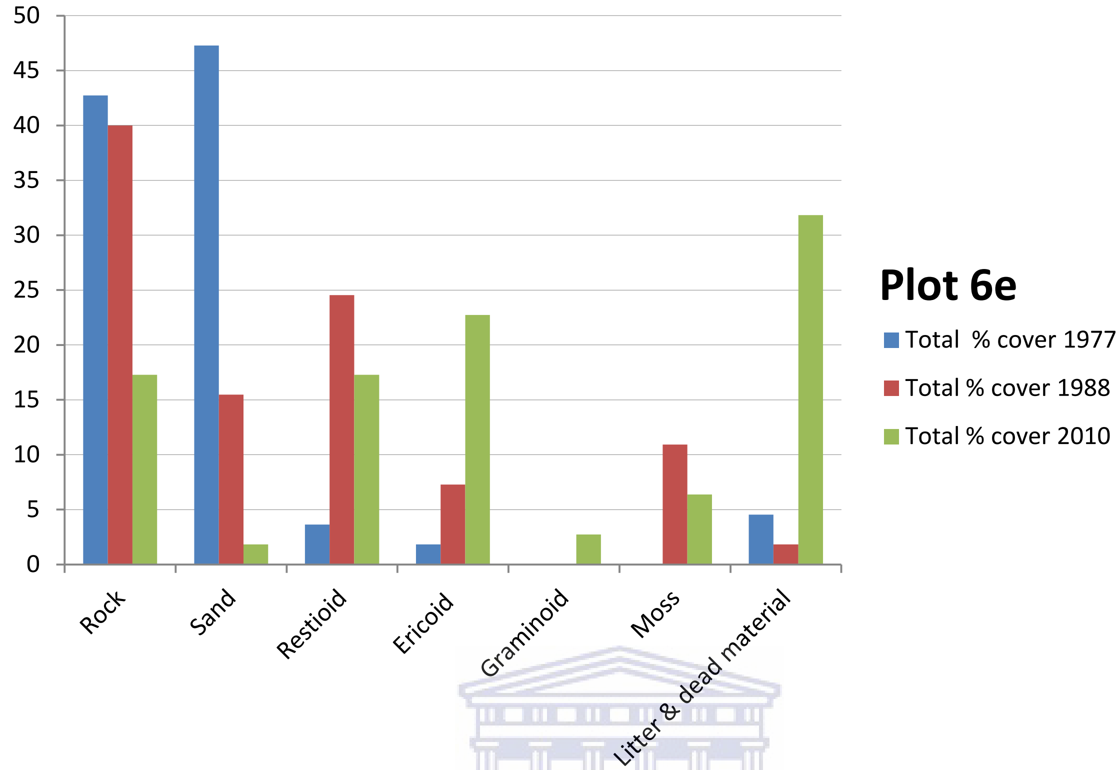

Figure 28. Total cover recorded from a transition matrix cell overlay in Plot 6e for the various broad habitat categories in 1977, 1988 and 2010.

Plot 7

The two paths evident in the 1977 and 1988 images had almost disappeared by 2010, which was the expected trend following the 1997 upgrade and protection from trampling (Figure 29). A steady increase in vegetation cover occurred from 1977 to 2010, and bears a similar pattern to the Plots 4e, 5e and 6e in terms of the relationship between recovery of restioids in 1988 (1977 = 27%, 1988 = 45 %, 2010 = 23%) and accumulation of free-standing dead material in 2010 (1977 = 9%, 1988 = 3 %, 2010 = 36%) (Figure 30). The original restioid recovery spike in

1988 is reflected in the 2010 image; only the restioids carry a far greater proportion of dead material.

There was a negligible change (decline) in restiod growth over the three time periods (1977 = 10%, 1988 = 11 %, 2010 = 8%). Gradual and marginal increase in graminoid (1977 = 0%, 1988 = 3 %, 2010 = 4%) and Moss (1977 = 0%, 1988 = 1 %, 2010 = 3%) occurred. Grasses are visible along the most visible path (path on the right hand side of the image) in the 2010 image.

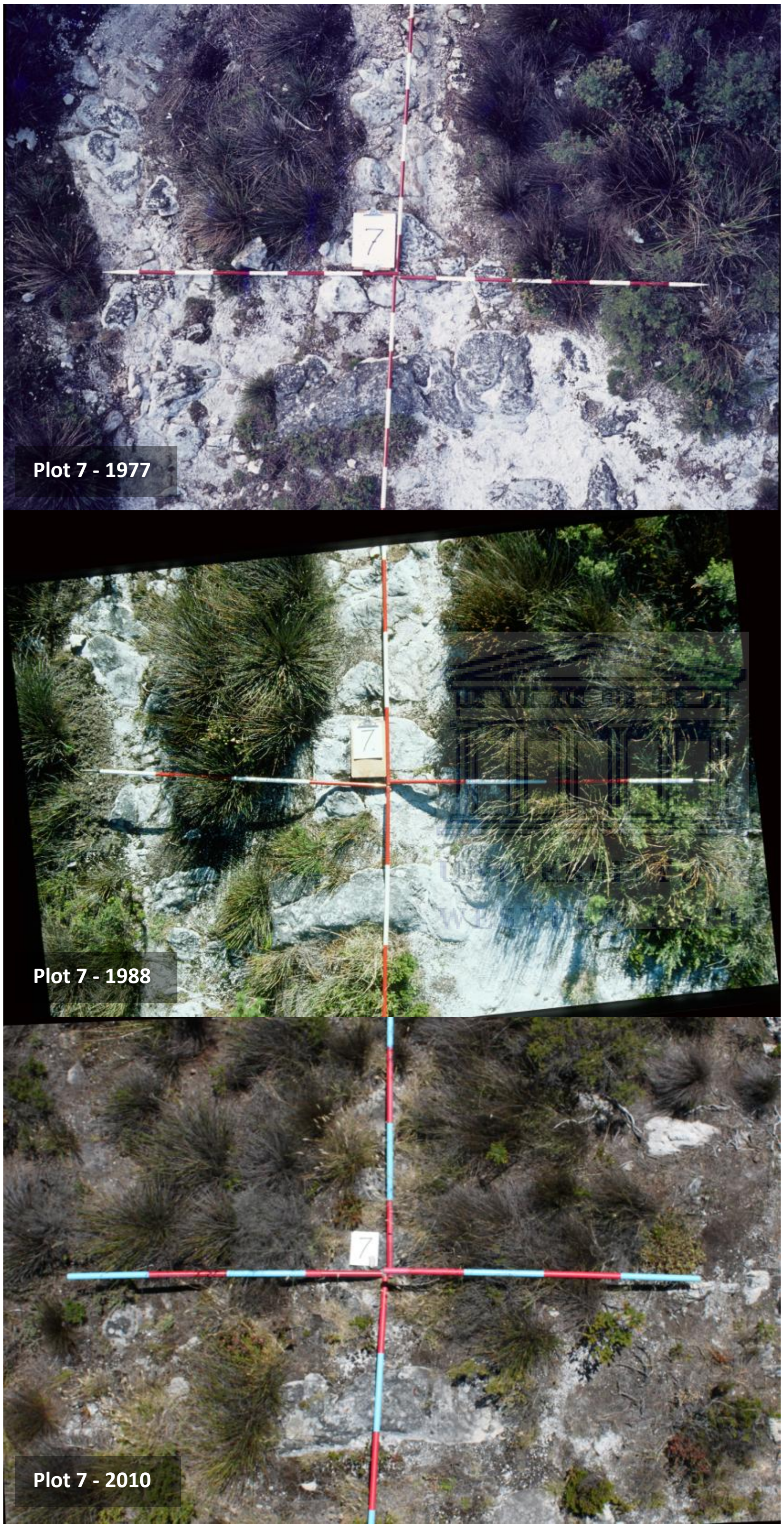

Figure 29. Photographic time series of Plot 7 recorded in 1977 (Coley), 1988 (van Coller & Kerbelker) and 2010. Well-defined paths are visible in the 1976 and 1988 images. Note the slight recovery of vegetation cover in 1088 and almost complete disappearance of paths in the 2010 image – the result of protection form trampling.

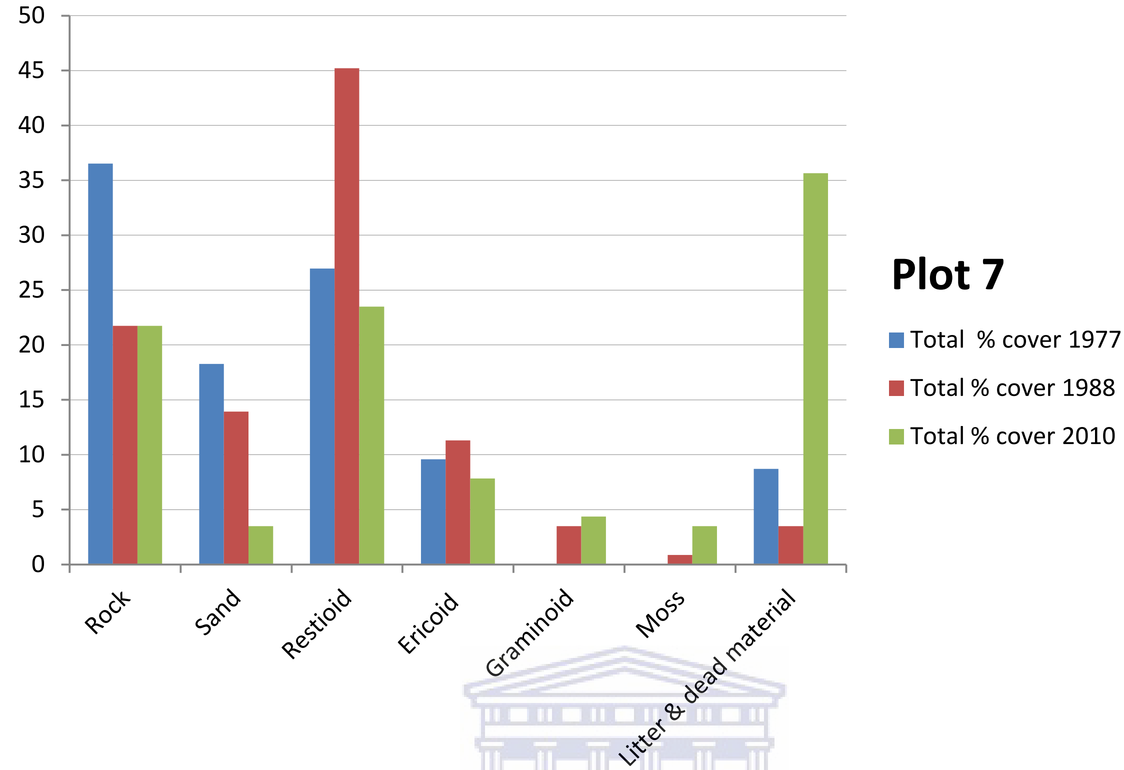

Figure 30. Total cover recorded from a transition matrix cell overlay in Plot 7 for the various broad habitat categories in 1977, 1988 and 2010.

Plot 8

Total vegetation, including moss cover, increase steadily from 1977 to 2010 (Restioid: 1977 = 22%, 1988 = 34 %, 2010 = 43%; Ericoid: 1977 = 0%, 1988 = 2 %, 2010 = 7%; Moss: 1977 = 3%, 1988 = 5 %, 2010 = 8%) (Figures 31 & 32). Litter and free-standing dead material underwent an initial decrease in cove from 1977 to 1988; followed by an increase to almost the same proportion of cover in 2010 (1977 = 20%, 1988 = 0 %, 2010 = 22%). The high cover of organic material can be seen over a layer of sand in the 1977 image, which explains the initial cover value. The increase in restioid and ericoid cover implies that the area was frequented less by tourists, which was most likely due to the cementing of portions of the main path system between 1977 and 1988. Interestingly, moss has only colonized the open sandy patches in the 2010 sampling period, which suggests that there was still trampling, albeit a lower intensity between 1977 and 1997. The 2010 image shows a marked recovery in vegetation compared to the previous time periods.

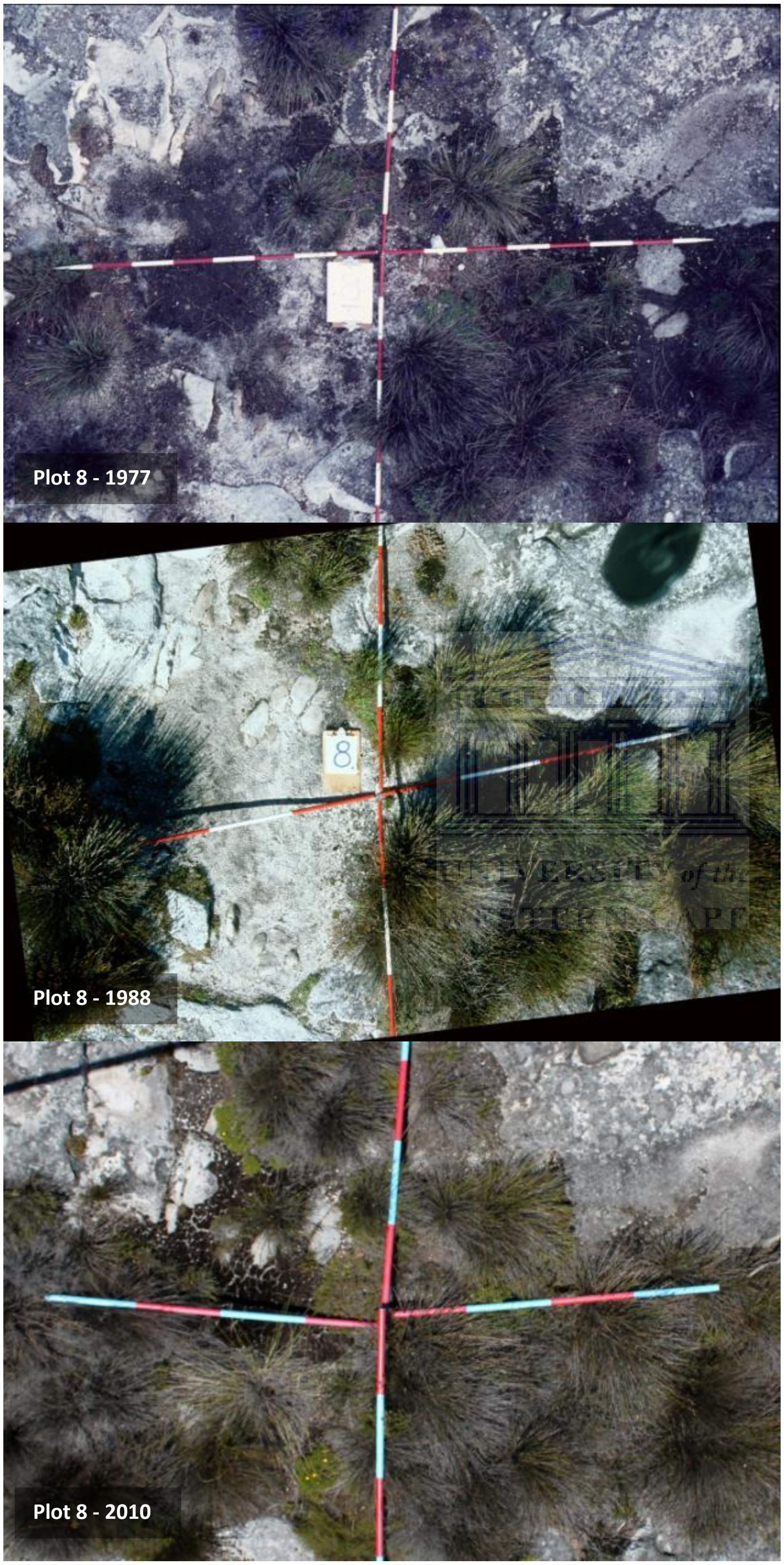

Figure 31. Photographic time series of Plot 8 recorded in 1977 (Coley), 1988 (van Coller & Kerbelker) and 2010. Not much change is occurred is evident between 1977 and 1988. Note the opens patches of sand for these periods and the recovery in 2010. Moss can be seen in the 2010 in the previously covered sandy areas.

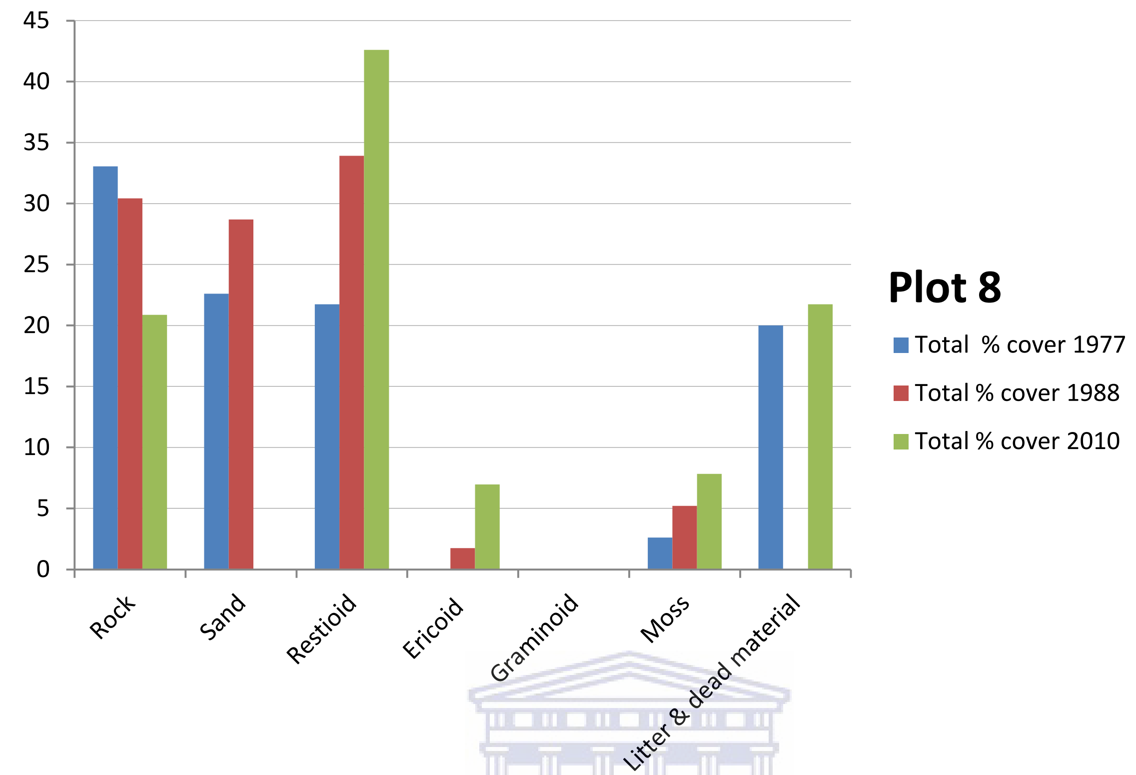

Figure 32. Total cover recorded from a transition matrix cell overlay in Plot 8 for the various broad habitat categories in 1977, 1988 and 2010.

Plot 9

Approximately half of Plot 9 was originally located along the path intersection, with the remaining half relatively undisturbed (Figure 33). The intersection consisted of a small path located perpendicular to a wider, well-used path. This lesser-used path had recovered partially in 1988 and 2010. The major path was still evident in 1988 and 2010. It is noted that a large proportion of the plot (almost 25%) was occupied by rock surface, which cannot support any vegetation owing to the lack of cracks or fissures present (Figure 34). Plot 9 displayed a similar trend to Plots 4e, 5e, 6e and 7 with respect to restiod, ericoid and dead material between 1977 and 2010. Restioid cover increased between 1977 and 1988; followed by a decline between 1988 and 2010 (1977 = 18%, 1988 = 26 %, 2010 = 4%). The decline in restioid cover in 2010 was linked to an increase in dead material (1977 = 18%, 1988 = 26 %, 2010 = 4%). Ericoid growth increased steadily over the 33-year period (1977 = 17%, 1988 = 20 %, 2010 = 28%) whereas rock and sand cover hardly changed for the entire period (Rock: 1977 = 30%, 1988 = 32 %, 2010 = 28%; Sand: 1977 = 18%, 1988 = 17 %, 2010 = 17%).

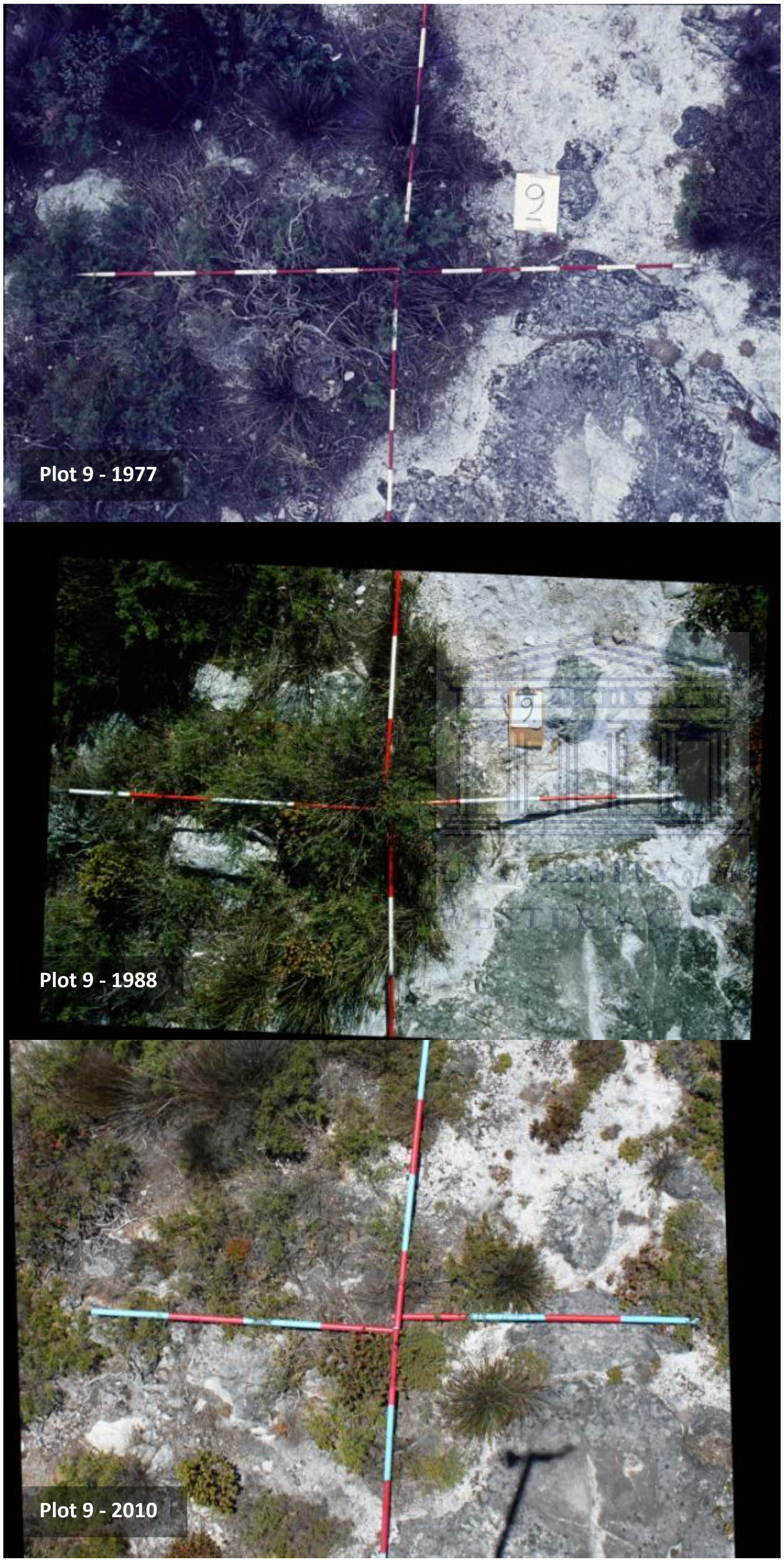

Figure 33. Photographic time series of Plot 9 recorded in 1977 (Coley), 1988 (van Coller & Kerbelker) and 2010. Marginal change in cover occurred between 1977 and 1988. In 2010 there was a substantial increase in ericoid cover. Also note the accumulation of dead material in the 2010 image and colonization of previously trampled sandy areas.

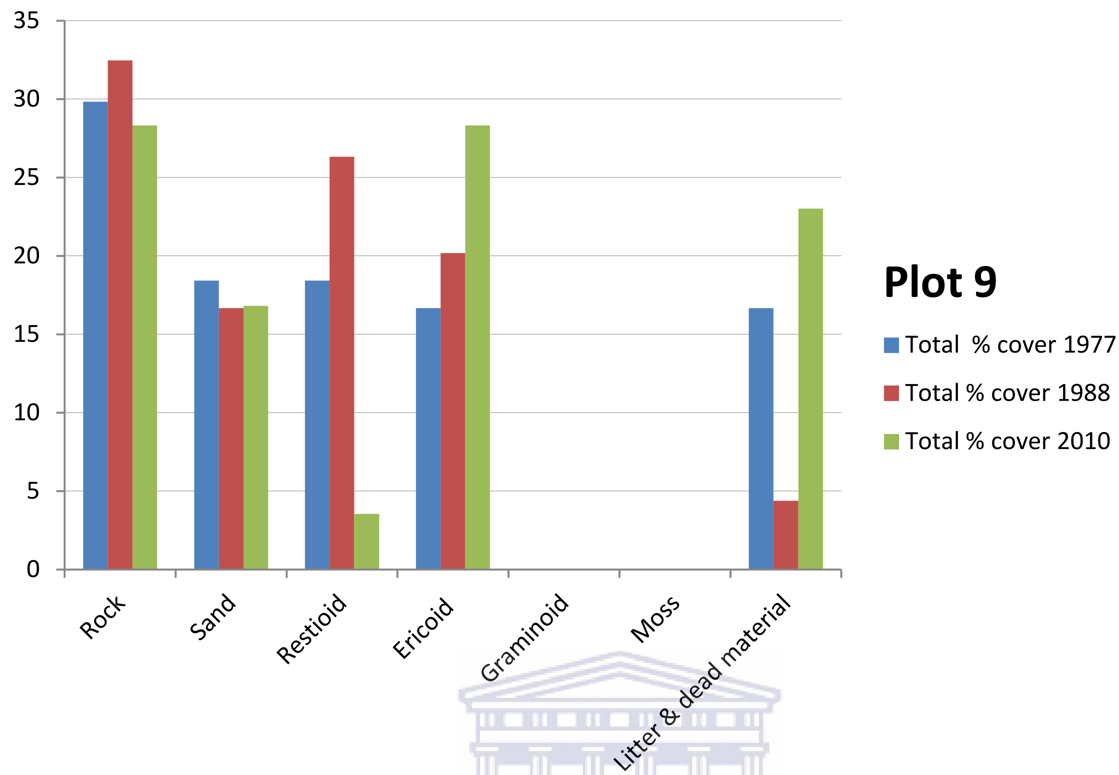

Figure 34. Total cover recorded from a transition matrix cell overlay in Plot 9 for the various broad habitat categories in 1977, 1988 and 2010.

Plot 10

A definable path and trampled vegetation is visible in the 1977 image whereas this area had undergone partial recover in 1988, followed by complete recovery in 2010 (Figure 35). The remaining portion of the plot comprises rock surface and would not support any vegetation. Interestingly the same shrub component was evident for both periods. The cover abundance data confirms that this shrub component consisted of *Cliffortia ruscifolia* and *Erica hispidula*.

The vegetation in Plots 10, 11 and 12 was not expected to change considerably, although Plot 12 was less protected as originally thought, since the images show a clearly defined path through the Plots 10 and 12. At least 30% of Plot 10 consists of bare rock cover, which declined marginally between 1977 and 2010 (1977 = 37%, 1988 = 33 %, 2010 = 31%) (Figure 36). The decrease in rock cover is attributed to an increase in ericoids, which was increase steadily over the 33-year period (1977 = 21%, 1988 = 27 %, 2010 = 37%). When considering the high percentage of rock cover this is a considerable recovery rate. Restioids remained almost the same between 1977 and 1988; followed by a decline of 7% between 1988 and 2010 (1977 = 16%, 1988 = 17 %, 2010 = 10%). The steady cover values for dead material (1977 =25%, 1988 = 22 %, 2010 = 22%) implies is thought to be an indication of low disturbance; meaning the plot has been in a similar state for a prolonged period.

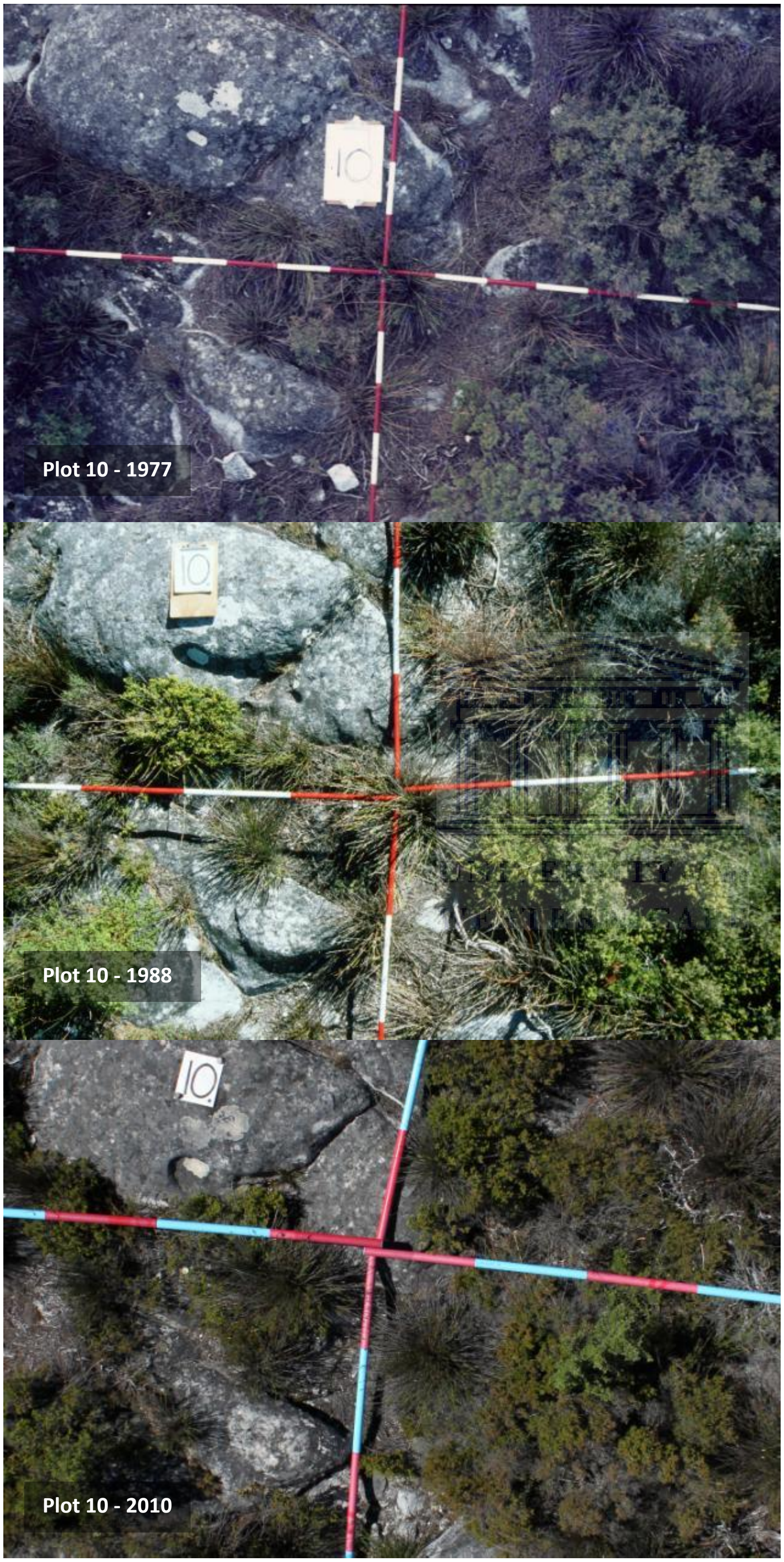

Figure 35. Photographic time series of Plot 10 recorded in 1977 (Coley), 1988 (van Coller & Kerbelker) and 2010. Overall change in vegetation cover is not noticeable across the time periods since there was only a change in the dominant categories. Restioid cover declined after 1977 whereas ericoids increased steadily, with the higher cover recorded in 2010.

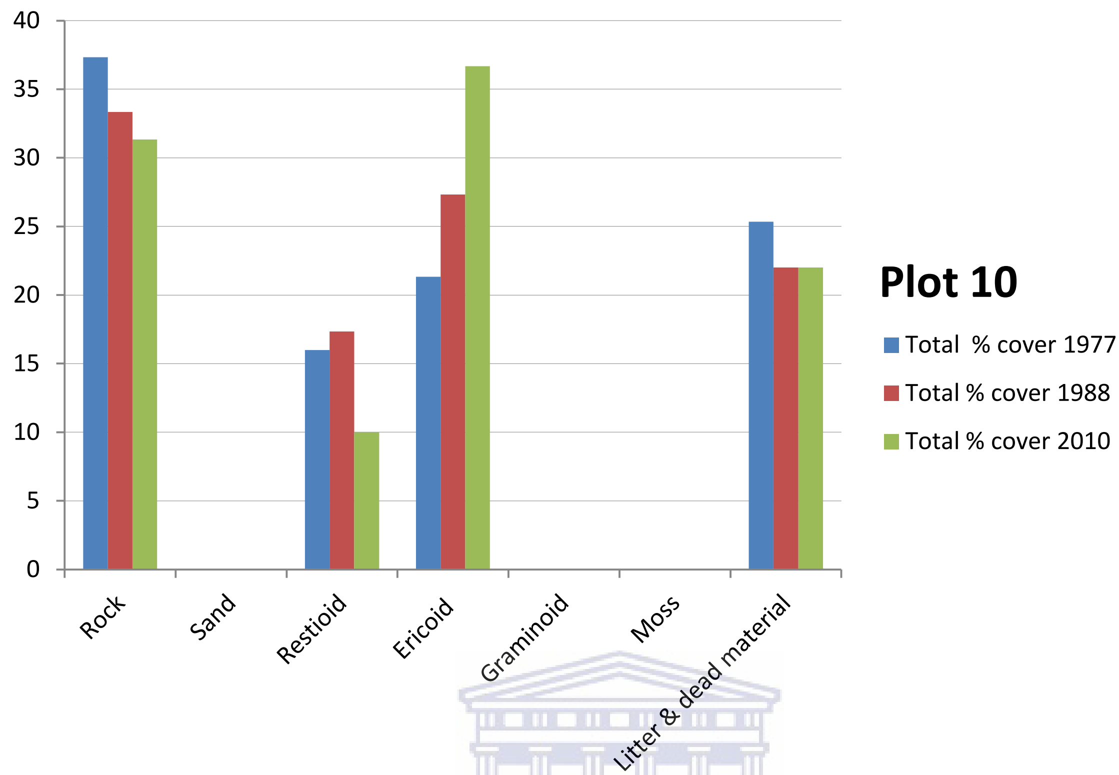

Figure 36. Total cover recorded from a transition matrix cell overlay in Plot 10 for the various broad habitat categories in 1977, 1988 and 2010.

Plot 11

Total vegetation cover, including restioids and ericoids increased from 1977 to 1988; followed by a slight decline in 2010 (Restioid: 1977 = 23%, 1988 = 36 %, 2010 = 19%; Ericoid: 1977 = 6%, 1988 = 19 %, 2010 = 27%) (Figure 37 & 38). Moss cover was absent in 1977 and 1988; implying that there may have been low impact trampling across the plot at the time. In addition, total cover of litter and free-standing dead material was highest in 1977; further suggesting that there trampling was at play.

There was a spike in restioid growth in 1988, followed by an increase in dead material in 2010 (1977 = 35%, 1988 = 10 %, 2010 = 26%). This pattern implies there was a slight decrease in trampling intensity sometime between 1977 and 1988 since the same trend occurred in the three exclosure plots (4e, 5e & 6e). The reduced trampling is most likely due to the cementing of the main path sometime in the 1980's. Then moss emerged in 2010 (3% cover) along with increased ericoid cover, which indicates a further lowering in tramping impact intensity. It is most probable that moss emerged after 1997, when tourist activity was concentrated onto the new path system.

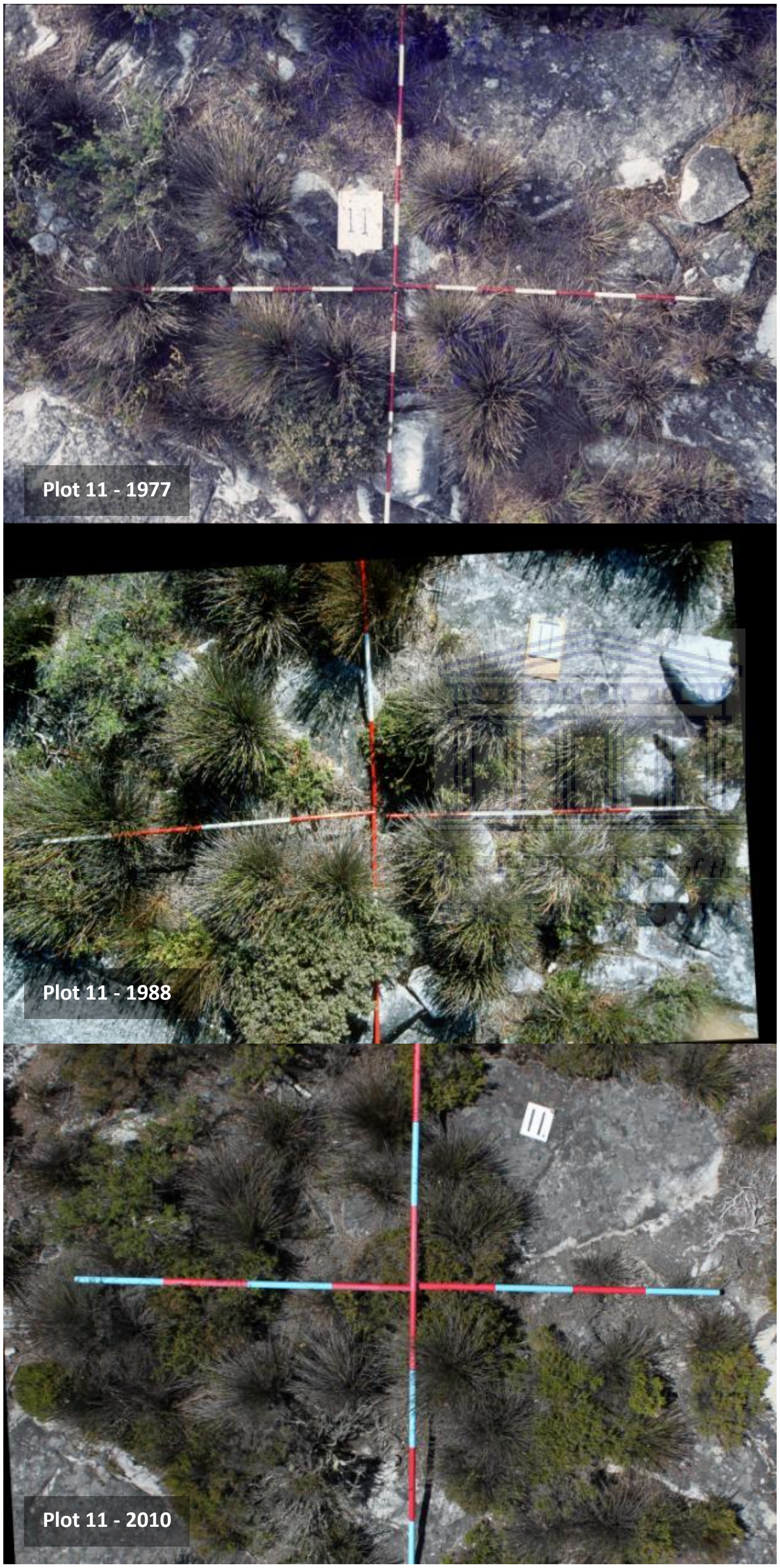

Figure 37. Photographic time series of Plot 11 recorded in 1977 (Coley), 1988 (van Coller & Kerbelker) and 2010. The low impact area, was slightly impact in 1977 and less so between 1976 and 1988. An increase in restioids and ericoids is evident between 1977 and 1988. Restioid cover then declines between 1988 and 2010, coupled with an accumulation of free-standing dead material in 2010.

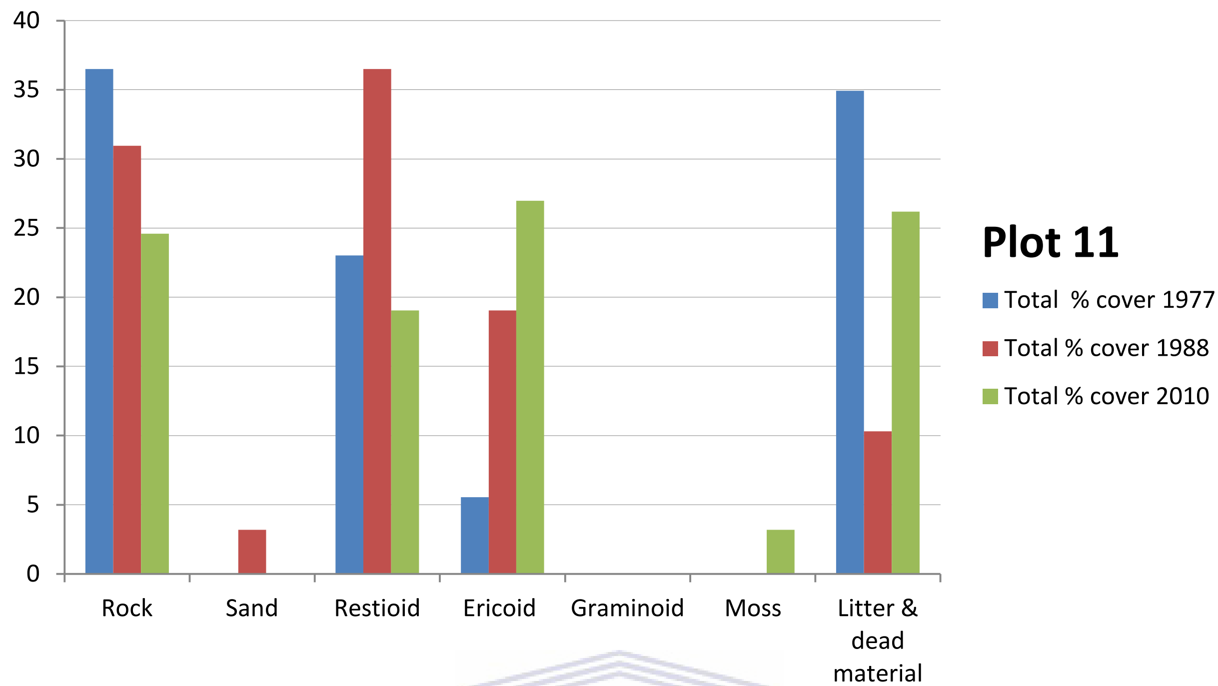

Figure 38. Total cover recorded from a transition matrix cell overlay in Plot 11 for the various broad habitat categories in 1977, 1988 and 2010.

Plot 12

A similar disturbance regime to Plot 11 is evident in Plot 12 (Figure 39). Based on the shift in vegetation and other cover categories it appears that trampling intensity, although low relative to Plots 1, 4e, 5e, 6e, 7, 8 and 9, was highest in 1977, slightly lower in 1988 and lowest in 2010. As with Plots 4e, 5e, 6e, 7, 9 and 11 there was a sharp increase in restioid growth in 1988, followed by a decline in restioid cover in 2010, which was linked to an increase in dead material in 2010 (1977 = 11%, 1988 = 41 %, 2010 = 13%) (Figure 40). In 1977 two paths are visible on either side of Plot 12, with a relatively high proportion of free-standing dead material evident. The dead material is attributed to damage of plant parts (stems and culms) since there was a lower amount of dead material evident in 2010. High cover of damaged dead material is clearly evident in the 1977 image (1977 = 34%, 1988 = 1 %, 2010 = 20%).

The path ‘scar’ had disappeared on the right hand side of the 2010 image, where recovery has occurred, however a new path had developed diagonally across the plot in 1988 and 2010. Partially recovery of the path on the left hand side of plot had occurred in 1988 and 2010. The marginal increase in ericoid cover in 2010 (1977 = 16%, 1988 = 30 %, 2010 = 33%) is indicative of lower trampling intensity. Ericoids, in particular brittle species such as *Erica pluckenetii, Erica coccinea, Erica hispidula* and *Erica ericoides* are sensitive more sensitive to trampling than restioids in terms of their brittleness and slower recovery rates following protection from disturbance.

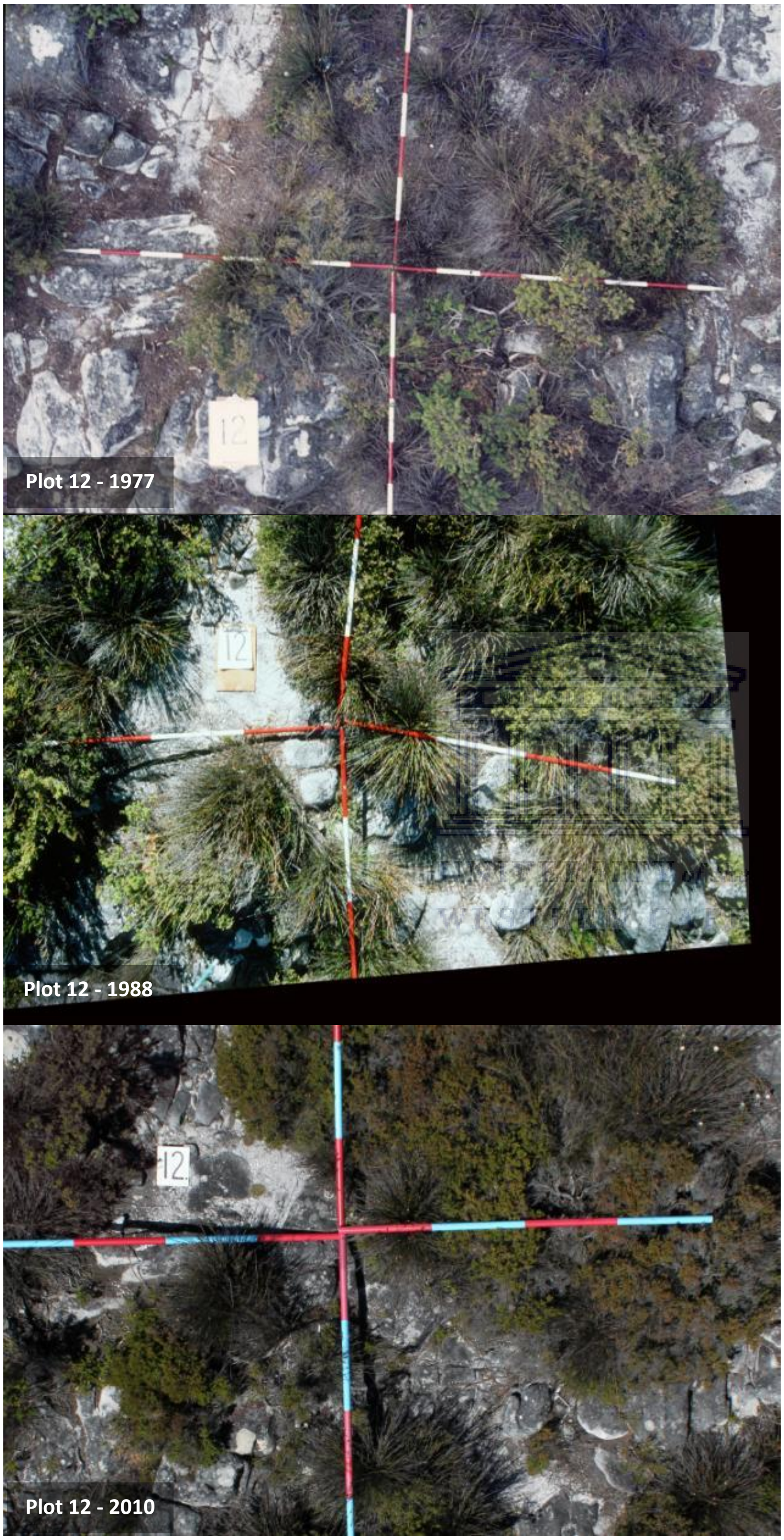

Figure 39. Photographic time series of Plot 11 recorded in 1977 (Coley), 1988 (van Coller & Kerbelker) and 2010. The area was most heavily trampled in 1977, as seen by the pathways and damaged vegetation. Note the dead material in 1976 compared to 1988, when restioid and ericoid cover increased. A new path developed between 1976 and 1988 (diagonal path), which can still be seen in 2010. Notable differences between 1988 and 2010 are a sharp decline in restioids and slight increase in ericoids in 2010. Dead material was also considerably higher in 2010.

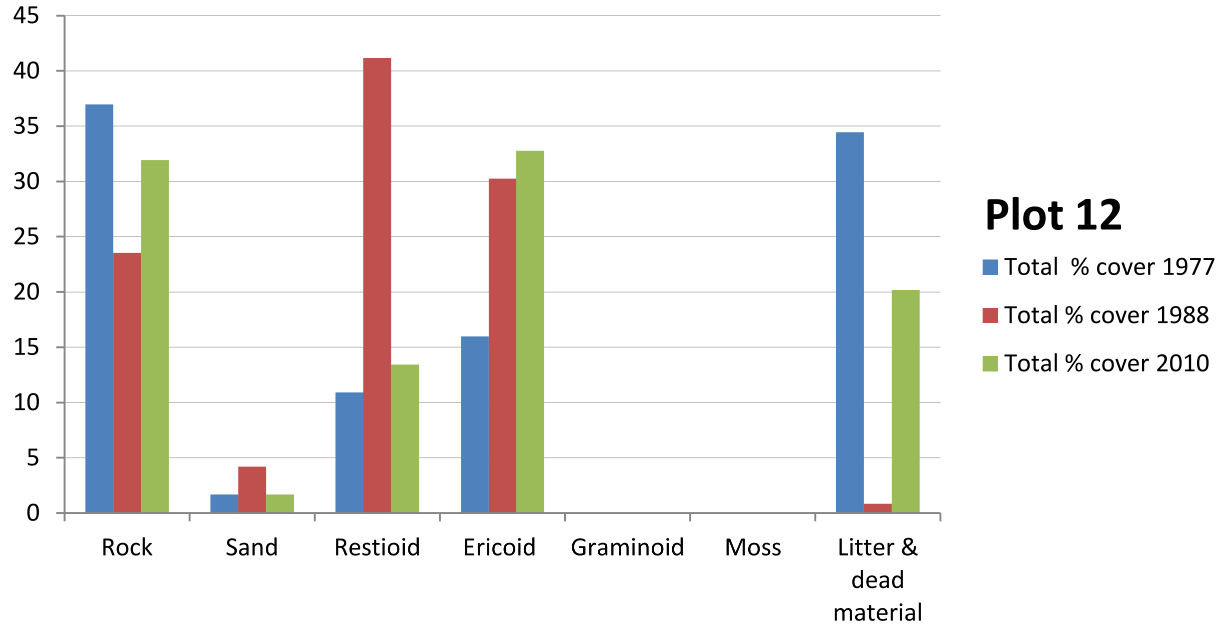

Figure 40. Total cover recorded from a transition matrix cell overlay in Plot 12 for the various broad habitat categories in 1977, 1988 and 2010.

Conclusions of overall cover change

The most apparent overall cover changes occurred between 1977 and 2010 in terms of rock, sand, ericoid, graminoid, and moss. The remaining two categories, restioid and dead material cover, were markedly different in 1988 than the initial (1977) and final (2010) sample periods. Figure 41 shows the overall trends expressed in cumulative percentage cover across all plots. Overall rock and sand cover decreased as expected over the entire period due to an increase in vegetation cover, however, the decline in restioids was not expected between 1988 and 2010. Furthermore, the spike in restioid cover between 1976 and 1988 was not expected, and suggests that trampling pressure was lowered over this period due to the cementing of some sections of path system. Accumulation of free-standing dead material and litter was linked with the decline in restioids, which is attributed to natural senescence due to lack of disturbance. Restioids would most certainly recover if the area is burnt in the future.

The overall recovery of ericoid, graminoid and moss cover lagged behind restioid recovery between 1977 and 1988, yet increased steadily between 1988 and 2010. The gradual recovery of ericoids is attributed to a higher susceptibility, or sensitivity, to trampling in the absence of fire. This trend may have been different if the area was burnt between 1977 and 2010, since reseeding species of restioids and ericoids would be competing in the gaps not occupied by resprouters. A decline is restioids raises some concern since the category had accumulated a high proportion of free-standing dead material, implying overall decline of restioids will increase with increased protection from fire and low intensity trampling disturbance. In natural fynbos systems high amounts of senescent material are indicative of old, un-burnt vegetation stands, with the amount of dead material being dependent on factors such as vegetation age and climax height. Other factors include floristic composition, which influences vegetation structure, which is influenced, in part, by factors such as fire history, wind protection, soil depth, nutrient and moisture availability.

Moss, or soil biogenic crust, cover, is an important indicator of trampling disturbance since this group disappeared in the study area with trampling. This is due to the moss; most likely *Archidium* sp. and *Pleuridium* sp. in the study area (Hedderson, pers. comm. 2013); being highly sensitive to trampling and due to habitat preference on the flat and open shallow sands, where informal paths tend to occur because the substrate is flat. It is important to distinguish between the effects or seasonality and the apparent disappearance of moss during the dry period. This can be differentiated on the presence of a dry crust over the sand during summer in contrast to a bare sandy surface. Mosses go through a seasonal green 'flush' during the wetter winter months but were observed as grey crust during the dry months in the study area, indicating permanent 'residence'. During dry spells moss becomes grey and crusty but retains its cover provided the area is not disturbed.

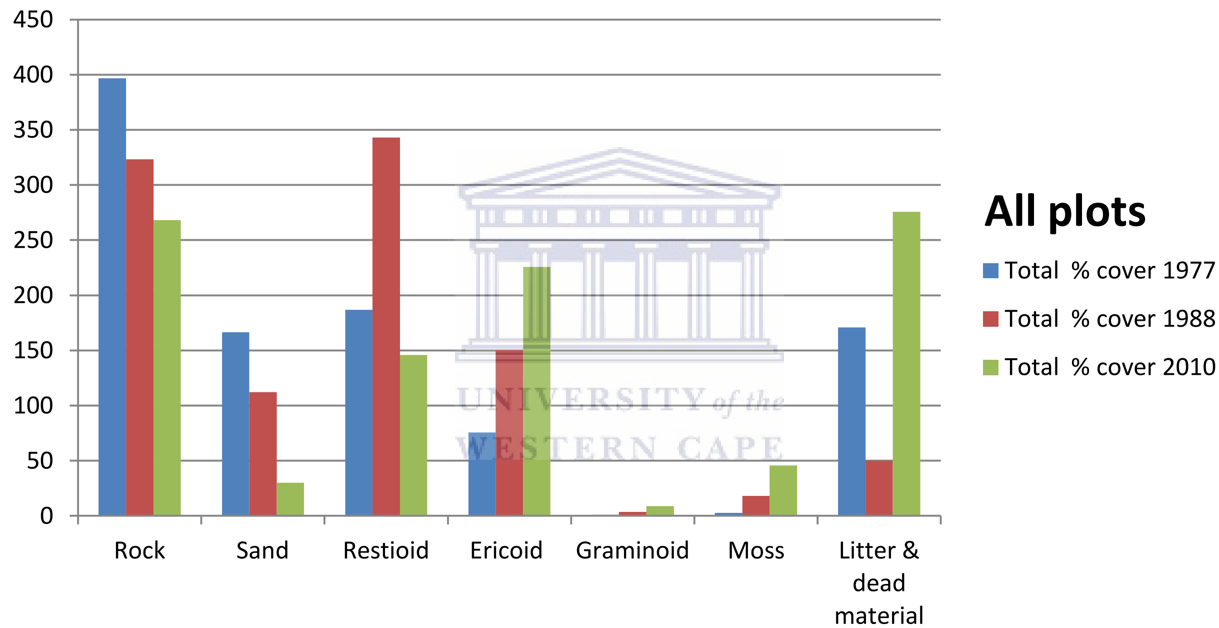

Figure 41. Cumulative total percentage cover recorded from a transition matrix cell overlay for all plots (Plots 1, 4e, 5e, 6e, 7, 8, 9, 10, 11 & 12) for the various broad habitat categories in 1977, 1988 and 2010.

4.6.1. Comparison of cover estimation versus counted cover

An analysis between the estimated versus actual cover for each of the transition matrix categories was carried out in order to determine what proportion of estimated values lie within

10% of the actual counted cover values (Appendix D). This was carried out in SAS (Statistical Software Information Kit) with the assistance of by Prof. Richard Madsen (statistics consultant at the University of the Western Cape). The scatter plot shown in Figure 42 illustrates this. Of the number of cases that were out by more than 10%, litter and free-standing dead material was off by the most at nine out of 30 observations; or 30%. The remaining proportion of categories that were out by more than 10% was scored as follows: ericoid = 3.33%; graminoid = 0%; Moss = 3.33%, restioid = 16.67, rock = 10% and sand = 3.33%. The litter and free-standing material were not acknowledged as acceptable in terms of comparing with the actual counts. Interestingly the second worst score was for restioids – the category that accumulated the highest amount of free-standing dead material. Thus if estimates were off for either category it would influence the result of the other category. In conclusion, the estimation versus actual cover data did not compare favourably; and since restioids and dead material are considered dependent categories and are key components in fynbos systems. This is a key finding since cover estimation is a well-accepted and commonly used vegetation assessment method. The comparison shows that a grid overlay with tallied counts is more accurate. This also affirms the potential inaccuracy of the Braun Blanquet cover abundance scale which has a 25% leeway between the higher scales. This suggests that vegetation plot cover is best measured using either (1) the photographic grid overlay method or (2) sub-divided plot quadrats, which would provide a higher level of accuracy, which is in effect what Coley originally did by dividing each plot into eight 2 m x 1 m quadrats, and assessed these individually.

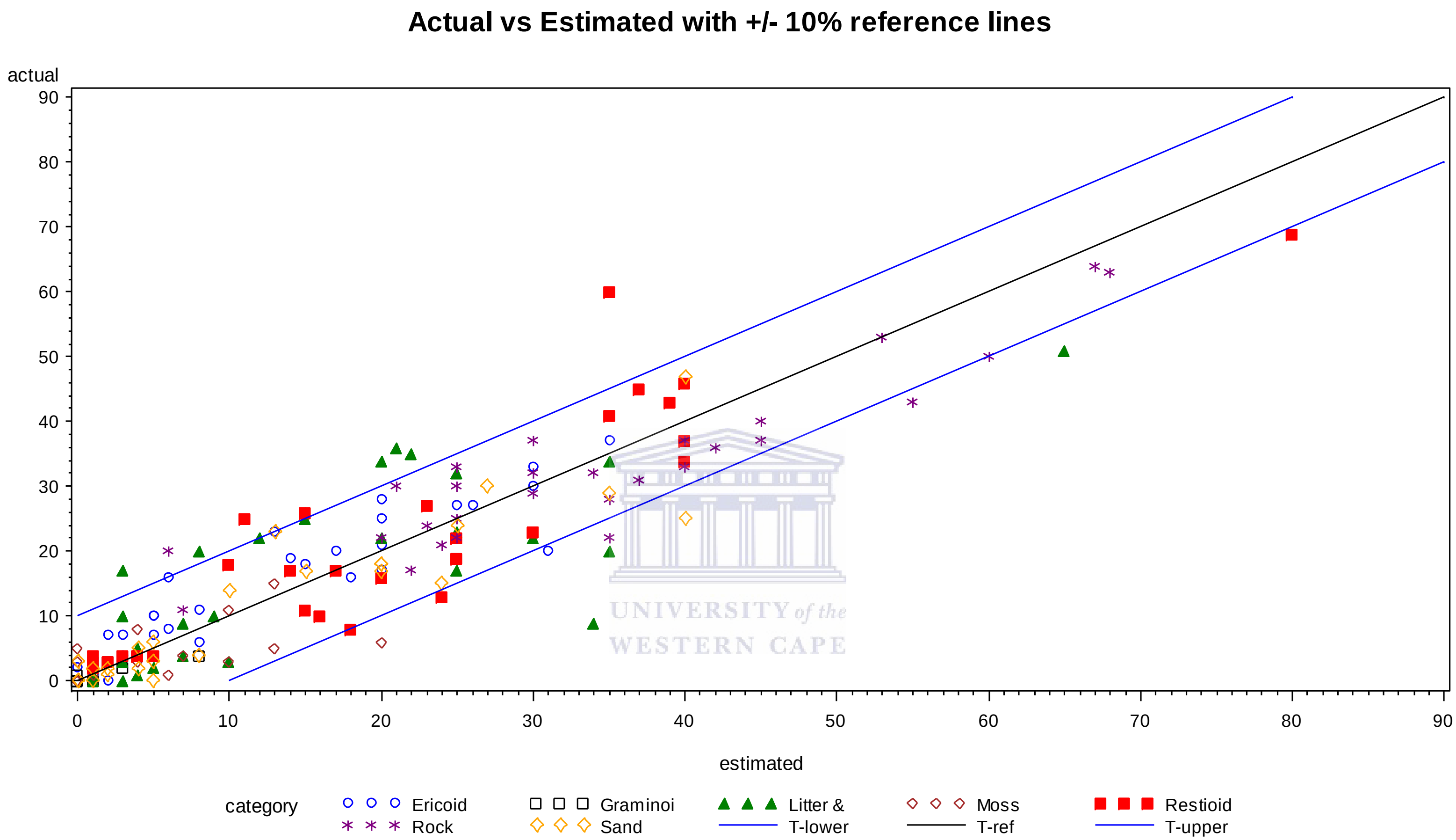

Figure 42. Comparison plot of 'actual' versus 'estimated' percent cover obtained from counts from a transition matrix cell overlay and visual estimation respectively for all plots (1, 4e, 5e, 6e, 7, 8, 9 , 10, 11 & 12) of the various broad habitat categories in 1977, 1988 and 2010. The identity line (black) is shown along with the +/- reference lines (blue). The plot was produced with help from Prof. Richard Madsen, using SAS (Statistical Software Information Kit). Note there are a number of outliers (9 out of 30 or 30%) in the litter and free-standing dead material category.

4.7. Comparison of vegetation communities with past studies on the Upper Table

In order to determine whether previous studies of vegetation communities on the Western Table would provide a better understanding of the phytosociological data collected by Coley (1977) and Emms (2010), a comparison with a study by Laidler et al. (1978) was carried out. Plant communities identified by Laidler et al. (1978) phytosociological study of the Upper Table is the only data set of its kind that compares with Coley and Emms. A comparative phytosociological table was compiled, incorporating these three data sets; presented in Table7.

It is important to highlight that Laidler et al.'s study area was not confined to the Western Table since this included the entire Upper Table (Eastern and Western Table). In addition, the position of each sample plot was not distinguished as being from either Western or Eastern Table. The plots were similar in size, with Laidler et al.'s plots measuring 25 m^2 (5 x 5 m) and Coley and Emms's plots measuring 16 m^2 (4 x 4 m). Furthermore Laidler et al. sampled 38 plots across various habitats, with variation in soil colour, rock cover, moisture levels (temporarily moist, wet or seasonally wet) and slope (steep, moderate, gentle or level). Since Coley's plots were placed in level to gently sloping, generally well-drained habitats, plots positioned in this same habitat type, only plots selected from Laidler et al.'s samples were used. Furthermore since only perennially identifiable species were recorded by Laidler et al., the two species, namely *Disa bracteata* and *Tritoniopsis unguicularis,* were removed from Coley and Emms's data.

The comparison between Laidler et al. and Coley's plots is intended to contextualize the communities in relation to other communities on the Upper Table and to identify any distinct differences, if any. Any differences found between the two sampling areas would confirm high heterogeneity, which appears to be present across different habitats as well as similar habitats (fine-scale heterogeneity). Wetland communities, for example, are expected to be more homogeneous than the dry land communities on the Upper Table. The extensive stands of the restioid *Elegia mucronata* is based upon a homogeneous habitat type, which is essentially governed by wet conditions. In dry land habitats water has not inundated the substrate, meaning there is more allowance for micro-variation in terms of varying moisture levels compared to wetland habitats.

When comparing the plots of Laidler et al. with the other sampling periods with similar habitat types it is clear that the communities differ in terms of (1) dominant species, (2) species composition and (3) number of species. The first noticeable difference at the community level is the *Thamnochortus nutans-Elegia ebracteata* Community, which is present in Laidler et al.'s reconfigured data. Coley's plots are characterized by a *Restio perplexus-Anthospermum aethiopicum* Community, which was characterized by high disturbance in all but three plots (Plots 10, 11 & 12). Laidler et al. make no mention of placing sample plots in disturbed areas. Thus it would be expected that these undisturbed plots would be more similar to Emms's plots since these areas were protected for some time. Lack of fire, however, has probably prevented any major shift in terms of species composition. This is complicated by the fine-scale heterogeneity, which is likely to result in different communities over short distances on the Upper Table. When comparing Laidler et al.'s data with Emms's the similarities are, in fact, apparent between the dominant communities. As expected, by 2010, following protection from trampling after 13 years, the vegetation in Coley's plots changed to a *Cliffortia ruscifolia-Elegia* *ebracteata* Community – having greater similarity in terms of dominant species – with Laidler et al.'s communities.

The dominance of *Elegia ebracteata* confirms the earlier statement, when describing the 2010 communities, that the species has increased markedly in both cover and fidelity in the study area and is not under threat due to absence of fire, even though the species is a reseeder. Another restioid *Thamnochortus nutans* also reverted back to similar cover levels between Laidler et al. and Emms's sampling periods. In 1978 Laidler et al. recorded 100% faithfulness of the species in their sample plots, whereas in Coley's plots the species was present in 30% of plots. This increased to 70% by 2010, indicating that the communities are reverting back to their original composition. A similar pattern can be seen with *Restio bifidus*, which was present in Laidler et al.'s sample plots in 67% of plots but occurred in 25% of Coley's plots in damaged vegetation in 1977. This increased to 70% in 2010.

Additional faithful species in 2010 community include *Erica hispidula, Anthospermum aethiopicum, Erica plukenetii* and *Ehrharta ramosa* subsp*. aphylla.* Three of these - *Anthospermum aethiopicum, Ehrharta ramosa* subsp*. aphylla* and *Erica plukenetii* are more faithful in both Coley and Emms's data but less faithful in Laidler et al.'s. The former two species may be the result of species persistence after the original 1977 to 1997 disturbance regime, however the increase in cover of *Erica plukenetii* in 2010 would either mean that the species did not occur in those plots sampled by Laidler et al. or that the species may be undergoing a lag recovery phase, which is based on the longevity of the species; meaning that there may be a natural decline if the same conditions persist as time passes.

Table 7. Phytosociological table of Upper Table taken from Laidler *et al*. (1978) and comparing Coley (1977) and Emms's (2010) surveys.

	Laidler et al. (1978)									**Coley (1977)**												**Emms (2010)**											
Species Relevés	**138**	**242**	**240**	**297**	**299**	**228**	**223**	**237**	**236**	**7**	**3**	**1**	**6**	**8**	**10**	**9**	**2**	**4**	**5**	**12**	**11**	**7**	**3**	**1**	**6**	**8**	**10**	**9**	**2**	**4**	**5**	**12**	**11**
Thamnochortus nutans	2	+	1	+	1	1	+	2	1	r	1	+										+			+	+	1	+		r		1	1
Elegia ebracteata	2	1	2	1	+	2	1	2	2	1	+	1	+	+	+	+	+	+	+			2		1	+	3	2	+		2	r	2	3
Erica hispidula	+	+	1	+	+	+		2	+													+				1	2	2		+	r	3	2
Ursinia nudicaulis		+	+	1	+		2	2	2		1	+	+	+	2	2	+	+	+	2	2					2							
Pentaschistis malouinensis		+	+	+		1	2	+	+																								
Cliffortia ruscifolia	3	1	+	+	+	+				+	2	+	r	+	2	+	+		+	+		1		2	2	+	1	2		2	2	+	+
Penaea mucronata	+	+	1		1					r	+			r		r			r								+					+	r
Restio bifidus			2	2	2	1		2	2										2	+	+	2				1	r	+			+	+	1
Anthospermum aethiopicum	+	+		+			+	+		1	+	+	+	1	+	+	r	+	+	+	+	1		1	1	+		+		+	1	+	
Ehrharta ramosa	+	+								1	1	1	+		+	1	1	+	+	+		2		2	1			1			2	r	1
Erica plukenetii	+	+	+							r	r	r	+			1	+	r				1		2	1	r		+		3	2	r	
Chrysitrix capensis						+	+	+		+	+	+	+	1	+	+	+	+	+	+	+										+		
Tetraria flexuosa			1			+	+	+	+																								
Ehrharta setacea subsp setacea					1	1	+																				r			1	r		+
Restio perplexus	1									2	2	2	r	+	2	2	2	2	1	2	2			1	2	+							
Pentaschistis curvifolia										+	+	2	2		+	+	1	2	2	+	+	2								1	1		
Crassula coccinea										2	2	+		2	1		2	3		2	2	r		1	r	r				+	+		
Lampranthus falciformis										2	+			1	2	1				2	+			1	+	r	r	1		+	r		
Hypochaeris radicata										+			1	1	+	1	1		2	+	+	r		1	1					1	1		
Pentaschistis tortuosa										r	+		2			+	+		2			+			+			r					
Erica ericoides										r	r				+						r							1					
Hymenolepis parviflora																						+		+	r								
Euryops abrotanifolius/Ursinia	+									+					r			+	+	+	1					+		r			r	r	
Schizaea pectinata	+																																
Aristea bakeri/capitata	2																																
Cassytha ciliolata	1																																
Leucadendron strobilinum	1																																
Elegia juncea/racemosa	+																																

Clutia polygonoides	+																																
Anaxeton arborescens	+				+																												
Restio sarocladus	+																																
Erica coccinea	1		+																														
Tetraria cuspidata	+		+			+		+	+																								
Watsonia borbonica subsp. *borbonica/tabularis*	+			+	+		+		+																								
Corymbium glabrum	+				+		+	+	+																								
Erica glabella subsp. *glabella*	2	+	+			1																											
Cliffortia atrata	1	+	+	+																													
Edmondia pinifolia					+	+	+		+																								
Elegia deusta					+	2																											
Mairia crenata					+		+																										
Centella caespitosa						1	+																										
Seriphium incanum					+	+	+																										
Villarsia ovata					+																												
Erica 244/1				+																													
Number of species	24	12	14	11	16	15	14	11	11	16	15	11	11	10	13	13	12	10	13	12	11	13	0	10	12	12	8	12	0	11	14	10	8

Apart from the above findings there is distinct separation in the form of a *shared* subcommunity found in Coley and Emms but not in Laidler *et. al*. The *Crassula coccineus-Lampranthus falciformis* Subcommunity. It is not clear why the two succulent species were not present in Laidler et al.'s plots and it can only be speculated that this is due to lack of habitat niche requirements, disturbance related factors or veld age. The presence of *Hypochaeris radicata*, *Pentaschistis tortuosa* and *Restio perplexus* in Coley (1977) and Emms (2010) but not in Laidler et al. (1978) indicates that Coley's plots were disturbed and Laidler et al.'s were not.

Other species trends

The shrub *Cliffortia ruscifolia* is not faithful throughout all sampling periods. The species is recognized as a characteristic species of the Western Table, particularly in Coley's plots. It is usually more common in well-drained, protected rocky areas and steep slopes, and does not thrive under excessively wet conditions and active disturbance. Old individuals are particularly common in fire and trample-protected areas, whereas regularly disturbed areas such as paths tend to support younger individuals. Thus the species tends to recover or become dominant as a result of either (1) long periods of protection or (2) after past disturbance, followed long periods of protection.

The aversion to wet conditions is explained in Laidler's' table. Where the wetland restioid *Elegia mucronata* occurs, *Cliffortia ruscifolia* is absent. Thus all relevés containing *Elegia mucronata* were removed from Laidler's table since this would mean comparing wetland habitats with dry land habitats. A distinction was made between Laidler's seasonally wet plots where *Elegia* *mucronata* was present or absent since the presence of the species was identified as an indicator of seasonally wet areas - that can be classified as wetlands, whereas those habitats not containing the species were more likely to be dry land habitats. The *Elegia mucronata* dominated wetlands are akin to what Sieben et al. (2004) describe as restio marshlands.

Species diversity between the three sampling periods shows a higher species count in Laidler et al.'s plots (14) than Coley (12) and Emms (11), showing a slight decline in average (perennially visible) species numbers. This difference is, however, too marginal to draw in conclusions from.

Conclusion

From the comparison between Laidler et al. and Coley and Emms, it is clear that the plant communities are not as distinct as when viewed in the field. This is an important finding since it suggests that the plot sizes were too big and captured more than one community per sample. It seems that the disturbance regime, in Coley's plots, confounded this issue since it would have resulted in less definable communities due to a complex array of colonization, competition, deterioration and succession, which would have lead to the disruption of the 'normal' community state.

The choice of the plot size may have been insufficient to sift through the complexity in the variety of species present and the associated micro-variation in cover. Smaller plots of say 4 m^2 would probably have better captured the communities. Large plots capture more heterogeneity, making identification of communities more difficult to the capturing of transitional communities within plots. The use of smaller plots would have made comparison between communities much clearer since one would be concerned with the small-scale changes rather than the broad level overlapping communities. In hindsight, a number of smaller test plots should have been included to test whether communities were more recognizable. This would most likely confirm the aforementioned study by Mustart et al. (1993), which showed that community pattern can be determined much more accurately using small plots (4 – 16 m^2) in fynbos phytosociological studies. It is important to recognize that heterogeneity is high even between Plots 1 to 9 – the 'at-risk' community phases - compared to Plots 11 – 12 (Tables 3 & 4) – the reference community phase (Bestelmeyer et al. 2009). It is important to consider the natural stages of succession and those influences relating to the absence of fire which has been discussed above.

Lastly, one of the important variables which were not sampled by Coley is soil. Soil properties may have important correlations to plant cover, more specifically species dominance, which is a limitation in this sense. However, the most crucial component, vegetation cover, was sampled and, furthermore, the important trigger driving the change in state (trampling disturbance) was known. In a study of mountain fynbos communities Campbell (1986) found no correlation for distinguishing non-fynbos/fynbos vegetation based solely on the soil chemistry variable. Campbell notes that there are also soil moisture relations relating to different textured soils, which can override the role played by nutrients. Thus although soil properties are important, the assumption is that trampling disturbance is the overriding driver of vegetation change in the study area.

CHAPTER 5: CONCLUSIONS AND PRACTICAL IMPLICATIONS

5.1. Key findings

The original purpose of Coley's study was to provide a means of monitoring the long-term impacts of human trampling in the vicinity of the UCS, and to use the monitoring information to inform management on a best way forward in terms of the ecological fate of the affected vegetation. Therefore this monitoring programme should be regarded as a type of long-term impact assessment and long-term monitoring of vegetation change. Although I consider the approach using low level photography for recording the visual changes as the best rapid assessment of change, and further recognize the need to obtain hard evidence in the form of species cover change, the Braun Blanquet method, in particular the BB percentage scale, seems to have complicated the study unnecessarily. Coley's self criticism of the quadrat-divided plot evaluation technique, as being too intensive and difficult to repeat for rapid assessment was correct in my opinion, however, the level of detail attained from this system is considered to be superior in terms of accurately assessing the vegetation. His recommendation to treat each plot as a single quadrat was more suitable of repeat monitoring; however, the measurement of vegetation cover and condition could have been approached differently.

The Braun Blanquet method, because of the use of percentage cover ratings, is suitable for identifying plant communities, but less suitable for comparing permanent plots over time due to the leeway of 5% to 25% cover on the BB scale. The scale allows for less inconsistency between different field workers due to this percentage cover leeway but is a drawback for comparing relatively small plots in heterogeneous fynbos plots. Actual percentage estimation of firstly, whole-plot and secondly, each species, would have provided a more accurate comparison, provided a calibration reference was provided. This could have been achieved, for example, by placing brightly coloured string around all individuals or groups (stands) of a few sample species within a plot; each species being delineated by its own colour. Each species would then be assigned an actual percentage estimation. The plot could then be photographed using the low level aerial photography method and used as a point of reference for future field workers. Applying this technique, the margin of error between repeat assessments would be reduced. Furthermore the degree of change would have been more detectible due to potentially greater differences in cover value estimations.

The monitoring approach did nonetheless allow for the detection of change in the disturbance patterns between a period of high trampling intensity from before 1977 to 1997, followed by a period of protection from trampling once the plots became restricted access areas from 1997 to 2010, which confirms hypothesis 1 outlined in Section 1.3. Due to this protection the vegetation in the areas of high trampling intensity (all plots except Plots 10, 11 & 12) only began to recover after 1997. The two data sets from 1977 and 2010 were considered as the most important and accurate. Data sets from 1985 and 1988 were included but subsequently disregarded (except the low level imagery from 1988) for the data comparison purposes since significant mistakes were found such as misidentification of species. It should be emphasized that these data sets were undergraduate student projects that were not necessarily meant to be completely comprehensive. The 2005 data set was most similar to the 2010 period but was not deemed important since these two data sets were collected within a short interval and the 2010 data collection was considered more accurate. The two plots that were lost following the 1997 upgrade were disregarded from the 1977 data set when comparing this to the 2010 period. The removal of the exclosure plots in 1997 was unfortunate since this may have interfered with the findings of the study, since the vegetation in the exclosure areas may have been disturbed when the fences were removed.

Although the recovery of previously disturbed vegetation was expected following protection, at first within the original three exclosure plots, and then for all plots following the major 1997 upgrade, this study provides a unique set of evidence-based data for the Fynbos Biome. The study is unique in the sense that the data set comprises both photographic and species cover abundance values for permanent plots over a 33-year time period. The following key trends were found:

- Due to the introduction of a well–defined path network in the immediate vicinity of the UCS after 1997 there has been a marked improvement in the previously heavily trampled vegetation. It is thought that the vegetation has developed to a higher succession stage, with more biomass accumulated, along a gradient of different levels of disturbance with distance from the UCS. The reduced trampling has resulted from cableway tourists being confined to the demarcated path system since the 1997 upgrade. This is confirmed by the overall increase in total vegetation cover and general improvement in vegetation condition. Changes in the species composition and species sensitive to trampling have also occurred, indicating that vegetation communities were perhaps quite different prior to 1977 when Coley first surveyed the area (and possibly even as far back as 1928).

- The photographic records of plots provide the most rapid assessment at a glance yet can be used to ascribe quantitative comparisons using a transition matrix grid overlay method. The method proved effective for comparing broad categories such as rock, sand, ericoid and restioid cover, which does not require identification of species. The Braun Blanquet method was critical in this regard since species trends could be assessed based on the phenology of the dominant communities. Species that were known to be sensitive to trampling, for example, were key indicators for measuring recovery.
- An overall increase in ericoids occurred from 1977 to 2010, (Plots 1, 4e, 5e, 6e, 8, 9, 10, 11 & 12). The ericoid group has a lag recovery, with restioids generally recovering more rapidly after trampling disturbance. Restioids tend to decline over time in protected areas and are replaced with ericoids. A marked recovery in *Erica plukenetii* occurred in 2010, which shows that the species is sensitive to trampling and requires protection in order to perform optimally.
- Recovery of vegetation was marked by an overall increase in ericoid cover coupled with a decrease in restioids. A consequence of the plots being protected from trampling is high accumulation of free-standing dead material and litter.
- There is a strong relationship between recovery of restioids in the absence of trampling, (and probably also fire) disturbance, to increased time-related accumulation of free-standing dead material. This is due to natural senescence and can be linked fynbos ecosystems having long-term fire intervals.
- An additional observation during the study was the colonization of bare rock by moss, which consolidates accumulated patches of eroded and wind-blown sand. The moss

species form shallow communities with a proliferation of species seedling of various species, including grasses and the geophyte *Romulea rosea*. Moss was observed to be highly susceptible to trampling (Figure 43).

Figure 43. An example of Moss colonization over bare rock and the sensitivity to disturbance. Note the dislodged chunks of soil and moss caused by trampling impact.

- An ordination of plots sampled in 1977 and 2010 shows a clear difference between the plots, confirming the large changes that have occurred.
- Importantly the old path scars are disappearing; however these scars will probably still be evident in places in the long-term since the soils have been eroded to bedrock (in places) through trampling.
- In addition to plant species recovery, there was a marked increase in moss cover, a community that disappears under trampling. These are likely to be either *Archidium* sp. or *Pleuridium* sp. (Hedderson, pers. comm. 2013). Moss 'recovery' occurred in the open, flat sandy patches and in rock fissures. Moss communities are considered important since my observations were that these communities provide a nursery habitat for germinating plant species. It is expected that the moss communities will be reduced as

the shrub and restioid species canopies close over these habitats. As a consequence of increase vegetation cover, including moss cover, rock and sand cover decreased. Open patches of moss are not the norm in the study area. These reflect past disturbance and are therefore not considered to be the climax vegetation state.

- A major change in community composition occurred across all plots from 1977 to 2010, which shifted from a restio-shrub pair (*Restio perplexus-Anthospermum aethiopicum* Community) to another restio-shrub pair (*Cliffortia ruscifolia-Elegia ebracteata* Community). The shift to a *Cliffortia ruscifolia-Elegia ebracteata* Community must have resulted from the past trampling disturbance, which has allowed the resilient and long-lived *Cliffortia ruscifolia* to become dominant. This species is resilient to trampling and is therefore more dominant in the study area.
- A comparison of these communities with those identified by Laidler et al. (1978) shows that the communities sampled in 2010 are reverting back to a similar composition as those identified by Laidler et al. (1978). This is an indication that trampling disturbance is (1) detrimental to the vegetation on the Western Table and (2) that although it is known that trampling has a negative impact on vegetation this study confirms that protection from such disturbance leads to the recovery of mountain fynbos in the long-term.
- The reseeding restioid *Restio perplexus* is declining in the study area, which can be attributed to lack of fire needed to stimulate regeneration of the species. This may be the general trend on the Western Table. The decline of *Restio perplexus* after 1997 only, infers that the species requires disturbance for its long-term survival. In this instance the

disturbance regime was trampling but it can be deduced that fire would offer a superior form of disturbance for the species, which supports hypothesis 2 outlined in Section 1.3.

- The increased cover of *Thamnochortus nutans* recorded in 2010 is an important implication for the long-term survival of the species on the Western Table. The species was previously under threat due to high intensity tourist traffic and is now present in eight plots as opposed to three plots in 1977. This is an important positive conservation implication for the species on the Western Table. The Cape Peninsula endemic is currently listed as vulnerable (Red List of South African Plants 2012) and only occurs on Constantiaberg and Table Mountain. Conversely the reseeding restioid *Restio bifidus* underwent a decrease in cover and fidelity, and was naturally senescing in 2010, which suggests that fire is needed to stimulate regeneration of the population on the Western Table.
- No significant difference in species numbers or species diversity was found when comparing all plots species numbers in the 1977 and 2010 data sets (excluding species with BB value r = solitary, with small cover values). When comparing the three least disturbed plots (10, 11 & 12) the species diversity was expected to decrease due to lack of fire being the only factor influencing species change, since the area was not subjected to high trampling intensity. This was not the case and may be due to several long-lived species occupying the habitat space.
- The restioid *Elegia ebracteata* increased noticeably in the least disturbed Plots 10, 11 and 12. The proliferation of the species shows that it does not require fire for its long-term survival.

- A comparison between estimated versus counted cover, showed that counted cover is a more accurate assessment method.
- Although the vegetation on the Western Table has not burnt for 80 to 90 years this does not imply that all species will eventually die out. It is likely that some species have disappeared due to the obligate dependency on fire but many species are unaffected and will continue to dominate in perpetuity. This is probably why during the monitoring period no significant decline in species diversity was found since the vegetation has selected out the obligate fire-maintained species.
- Long-lived perennial species are therefore important components for the long-term stability of communities, in particular resprouting species. They are therefore useful in their application for long-term monitoring and for determine the underlying disturbance regimes in fynbos ecosystems.

5.2. Management implications for vegetation management

Although the study area has not been subjected to fire-disturbance for 80 to 90 years (SANParks 2012) the trampling impacts would most probably have mimicked some aspects of fire disturbance due to the gap creation effect of trampling. This disturbance would only have been experienced within the trampled areas and does not apply to the areas that were undisturbed. In the disturbed areas seed germination would not have been stimulated in the same way that fire and smoke acts. Hence it is thought that species diversity would have decreased with only a trampling disturbance regime, and the effect of least-fire disturbance, such as in the aforementioned Schwilk et al. (1997) study, could not be applied to the high disturbance plots but only the least disturbed plots (Plots 10, 11 & 12). If Schwilk et al.'s findings are also true for the Western Table, the notion of controlled burn cycles does not seem to be the logical way forward in terms of preserving high species diversity since the long fire interval may have resulted in local extinctions of obligate reseeders and short-lived resprouters in the low disturbance areas, implying that a controlled burn would not necessarily increase species diversity since the seed bank would be extinct. However, the changes that have occurred over the sampling period show that disturbance is needed to maintain several important species on the Western Table. A controlled burn would therefore most certainly maintain species diversity, which is likely to decrease if the study area is protected from disturbance in the long-term. A controlled burn could be implemented in stages or 'block burns' and is recommended for the long-term survival of the vegetation.

5.2. 1. Burning as a management tool for maintaining species diversity

Burning, as a management tool, poses several challenges, primarily the impact that this may have on tourism. The Cableway is open every day of the year, weather permitting, and has 800 000 tourist visitors from around the world annually (TMACC 2011). The prospect of a controlled burn during the operational hours of the cableway would impact on the tourism industry and revenue of the TMACC, including vendors and informal traders. This could be circumnavigated by night-time 'block burning', if this is deemed a suitable time for a burning operation, when the Cableway is not operational. Alternatively day time burns could be implemented at short periods of several hours per patch every 12 to 15 years. If the Western Table were divided into three blocks, then each block could be burned on a 12 to 15 year rotational burn cycle. Burn period could be implemented within short time frames; say 10h00 to 11h00 for each cordoned off block (e.g. Figure 44) and may become an important draw card for tourism soon after each burn – stimulated by curiosity and available information on each burn. A proposed block burn option is provided in Figure 45. The area in closest proximity to the UCS would have to be sacrificed since this zone is a safety risk due to the location of the restaurant and cable station buildings (Figure 45). It is recognized that the fine details and exact strategy of block burning would have to be prepared by SANParks.

Another approach, which may be needed prior to the block burn proposal, is to burn a small patch of vegetation and monitor the pre and post-fire changes. Positive ecological results would be gauged upon species diversity, with increased diversity of endemic species being supportive of a burn option for the Western Table. This would also apply to the much larger Eastern Table. A small patch (± 250 m^2) selected for a test burn is shown in Figures 44, 45 and 46. The patch is suitable since it could be burnt within an hour and forms an island surrounded by cemented paths.

A consequence of burning is that recently burnt fynbos causes ash litter that can easily enter the human eye when blown by the wind. It seems unrealistic and comical that tourists be given goggles and encouraged to enjoy the experience whilst the vegetation is regenerating but this should nonetheless be considered as a viable option in the case of larger block burn areas being burnt. The only alternative would be to erect shade netting along the paths to create wind breaks and to buffer the windblown ash. This latter option would not be ideal since it would not guarantee that the ash is not blown over and onto tourists. The process could still be achieved if wind breaks are provided along the paths but this option would also temporarily obstruct the uninterrupted 360˚ views. Ash will be blown away nonetheless after a short period of time.

A 'block burning' approach would be the most desirable management intervention since this would allow for a comparison between burnt versus un-burnt vegetation. Path burning would also reduce the amount of post fire ash, and could be reduced depending on the patch size determination. It is also not necessary to burn in the immediate vicinity of the UCS as this may cause damage that is unsightly (i.e. burnt Aloes and blackened pathways or walls) (Moll pers. comm. 2012).

Furthermore burning need not be a tourist deterrent. The stark contrast between burnt and un-burnt vegetation could be used as a vivid educational opportunity, through interpretation signage and an accompanying story of the critical role of fire in fynbos and the various stages of regeneration for example. A burn cycle of 15 to 20 years (or longer) could be carried out; meaning the impacts on tourism would be low.

Patch burning could possibly be accompanied by introduction of seed from the closest and most recently burnt vegetation patches in the vicinity. This should include shrubs of the Proteaceae such as *Leucadendron strobilinum*, which may have occurred here previously. This would also provide an opportunity to re-introduce the locally extinct *Protea grandiceps*, which used to occur on Table Mountain, Kloof Neck, above Camps Bay and Devils Peak (Rebelo, pers. comm. 2013). The survival success of these larger shrubs would indicate whether the soils are deep enough to support these species and would further prove whether these once occurred in the area. It is reasonable to assume that the habitat can support the species since the substrate is highly fissured, which would therefore support deep-rooted species.

Figure 44. A small patch of vegetation that would be suitable for a test burn. The patch, measuring ± 250 m^2, is partially protected by rocks and surrounded by paths on all sides, making it ideal for a controlled burn.

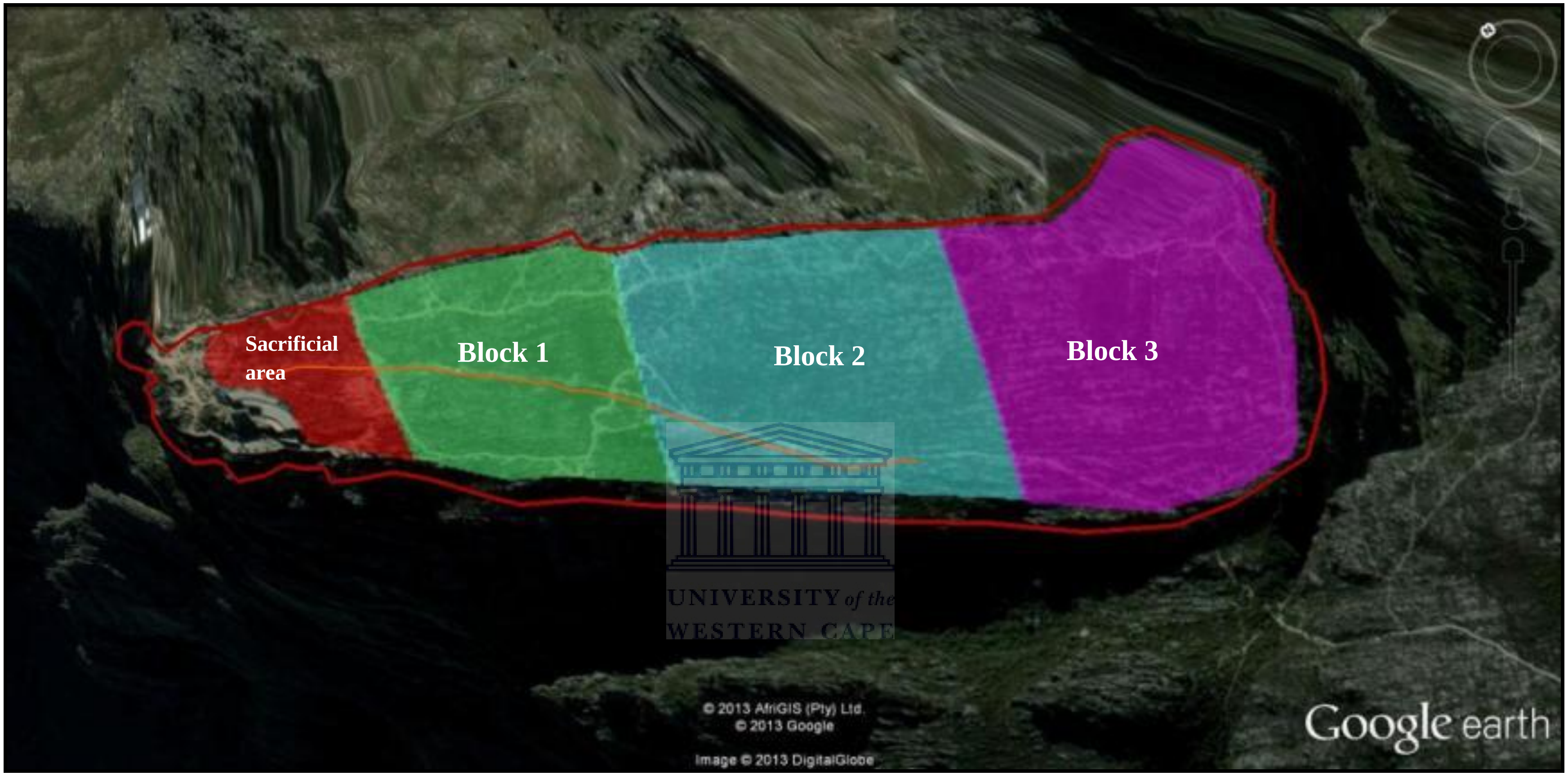

Figure 45. Google Earth ™ aerial image showing a proposed block burn plan. The block burn would be based on a rotational burn system, whereby each block (Block 1, 2 & 3) would be burnt every 12 to 15 years or so. It is proposed that the red shaded area be set aside as a 'no burn' sacrificial zone.

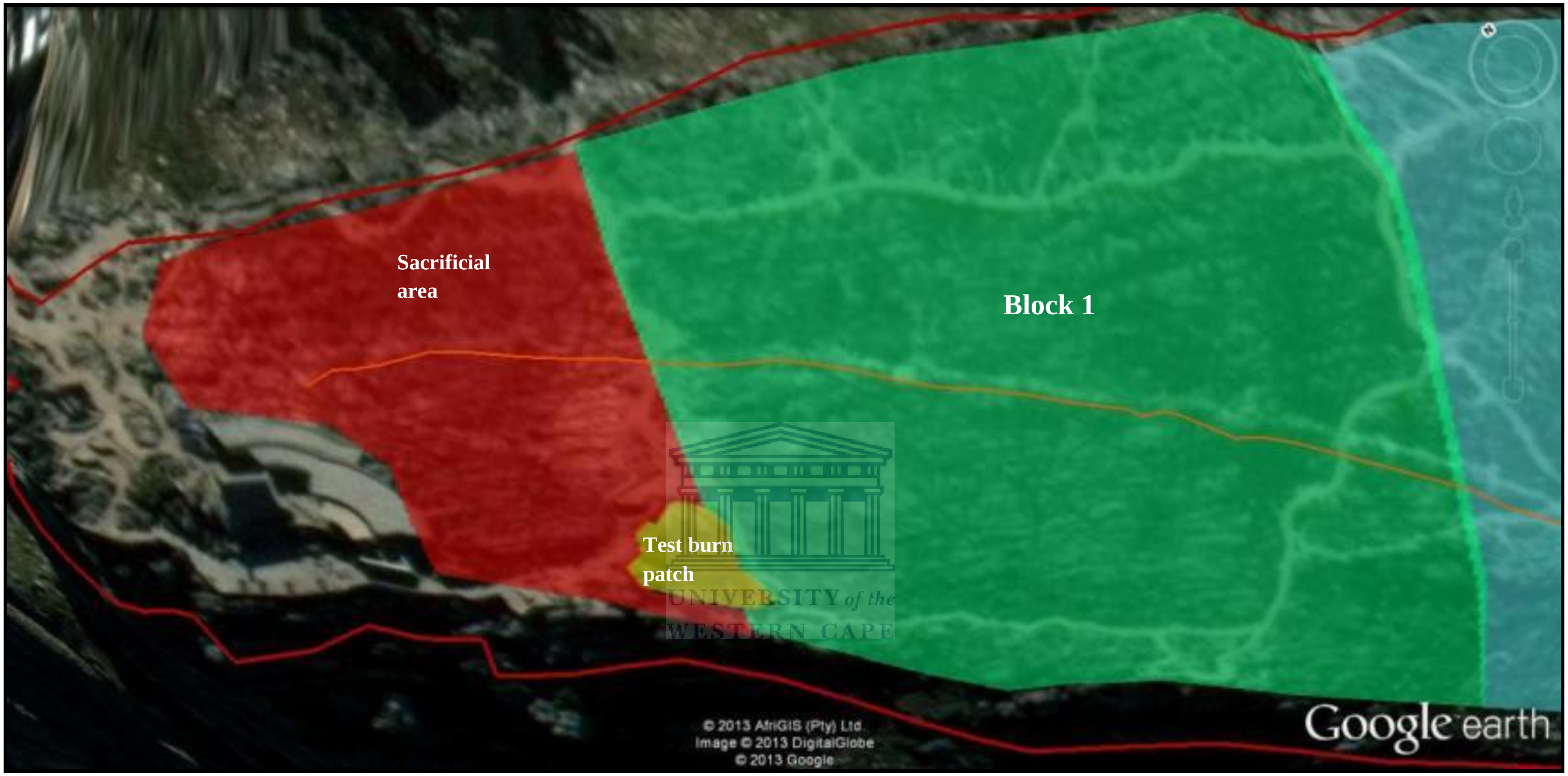

Figure 46. Zoomed-in portion of Google Earth ™ aerial image in Figure 45, showing the proposed test burn patch (yellow shading). It is proposed that the small patch (± 250 m^2) patch be burnt to show the effects of fire on the vegetation of the Western Table – an area that has not burnt for 80 to 90 years. The results would provide evidence for or against the benefits of the proposed block burn programme shown in Figure 45.

5.2.2. Management implications for path networks

The continued protection of the vegetation around the UCS is vital for the ecological health of this portion of the mountain. The demarcated pathways have now been shown to have a positive impact on the ecology of the vegetation, which would be similarly achieved for the related fauna and invertebrates. The existing path network on the Western Table is well managed and maintained by SANParks and provides access to a number of view points and hiking routes. An image overlay of the path network in 1980 shows that the previous informal path network consisted of a multitude of paths (Figure 47).

SANParks recognizes the existing and potential threats to the Table Mountain National Park's biodiversity as a result of the extensive footpaths and tracks which have had inadequate maintenance, incorrect alignment and poor design. Consequently an action plan to curb such impacts was initiated in 2003, after key areas were sufficiently addressed. The aim since then has been to upgrade the path network system of the Park, with the objective to complete all upgrades by 2013 (SANParks 2008). The present path network in the vicinity of the UCS is a vast improvement to the situation prior to 1997 and has allowed for the previous impacts to considerably reduce as result of the restricted access and should be remain this way. The implications of this study provided evidence of the importance of restricting tourist traffic in areas that are regularly visited. It also shows that denuded fynbos is resilient and does recover over time, proved that the substrate is not eroded too heavily by trampling traffic.

McLachlan and Moll (1977) pointed out that during the rainy season the paths leading from the UCS to Platteklip Gorge often becomes waterlogged and forces people to walk around wetter areas and temporary pools thereby widening the path through trampling. I have also witnessed this on the path(s) leading to Maclear's Beacon and although some excellent wooden boardwalks have been created in the marsh areas between Platteklip Gorge and Maclear's Beacon along the northern brim (Figure 13), there are only a few short sections of wooden boardwalks along the southern route. The pooling effect of paths certainly raises concern along this route and the relevant authorities should carefully review the possible future introduction of well-designed wooden boardwalks in impact areas. Following this an evaluation on the Western Table path network should be conducted to determine which areas may be more subjected to 'pooling' along the constructed paths, so that wooden boardwalks can serve to prevent path widening and enhance the walking experience of the visitor. Path widening also occurs where vegetation next to the path is already trampled, making it a suitable place for tourists to have a rest without hindering passersby (Figure 48). Lastly, where existing, constructed paths require maintenance or reconstruction, the use of cement should be avoided completely and substituted with natural sandstone instead of cement.

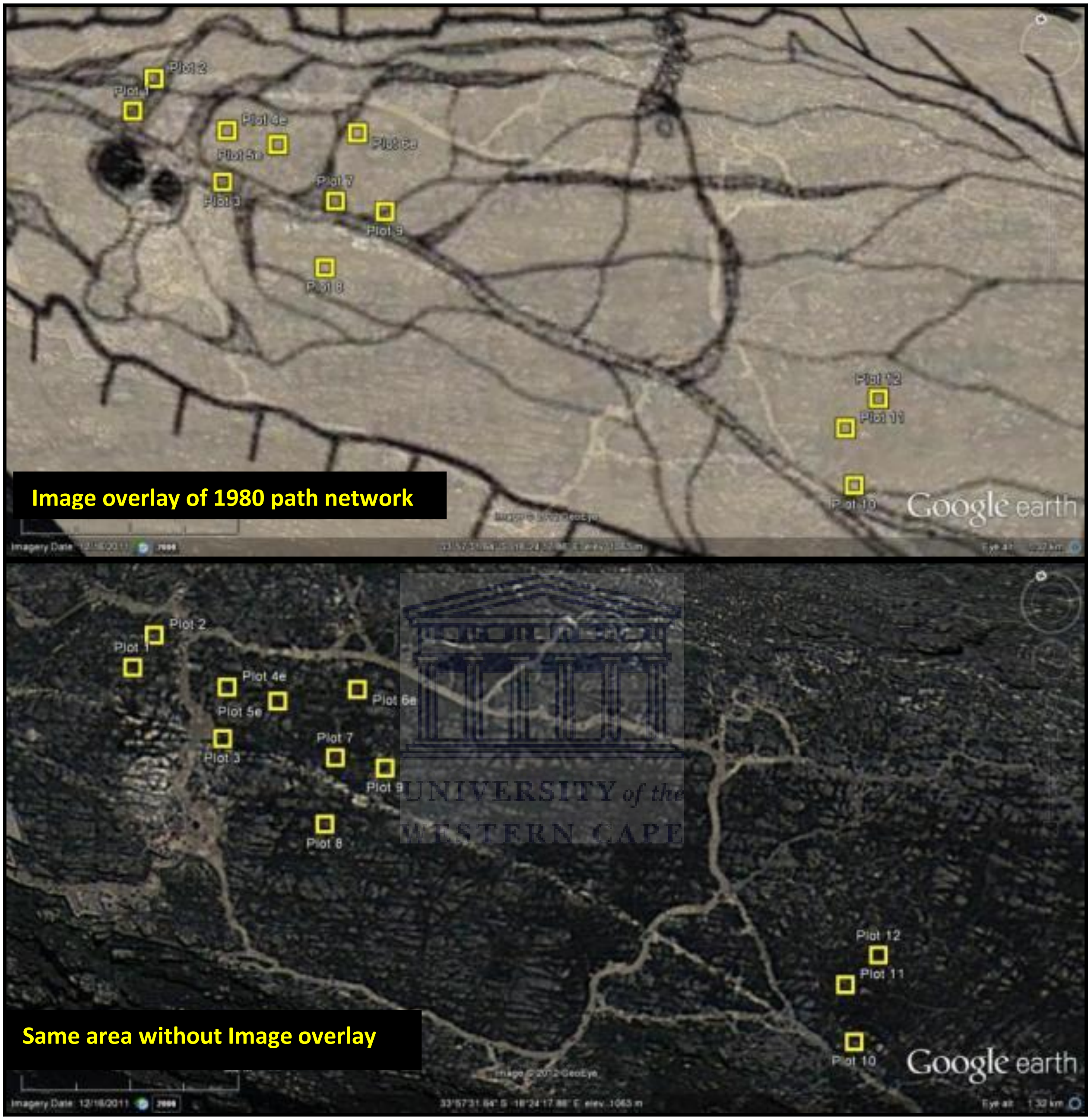

Figure 47. Google Earth ™ aerial images showing the comparison between the informal 1980 path network (Moll & McLachlan 1980) and the newly constructed path system following the 1997 upgrade. Base layer of both images from 2011 imagery.

Figure 48. Path widening caused by trampling along the path edge, where no barriers have been erected. These are, however, low impact, and occur infrequently with distance from the Upper Cable Station. The trampled species in the image is the restioid *Restio perplexus*.

It is important to identify high impact areas in all sections of the TMNP and provide suitable protection from all forms of physical disturbance such as trampling, mountain biking, rock climbing and vehicles within the various habitats and vegetation types. Currently it seems that management recognizes and properly manages visitor activity and impacts, whilst not confining visitor enjoyment and freedom. Hikers, for example, should be allowed to explore the more remote parts of the mountain whilst in a responsible, low impact manner. It is only when paths are frequented too often that signs of trampling disturbance become evident. Furthermore some vegetation types are more resilient than others. Where rocks climbers frequent the bases of cliffs there is often a thicket vegetation component due to fire protection.

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APPENDICES

APPENDIX A: Phytosociological table of Western Table communities surveyed by Coley (1977), Aubin (1985) Kerbelker and van Coller (1988) and Emms (2010)

	1977 relevés												1985 relevés											
Species	**7**	**3**	**1**	**10**	**9**	**2**	**4**	**6**	**5**	**12**	**11**	**8**	**7**	**3**	**1**	**10**	**9**	**2**	**4**	**6**	**5**	**12**	**11**	**8**
Restio perplexus	2	2	2	2	2	2	2	r	1	2	2	+	2	2	2	2	3	2	2	r		2		r
Anthospermum aethiopicum	1	+	+	+	+	r	+	+	+	+	+	1	2	r	1	1	1	r	+	2	1			2
Chrysitrix capensis	+	+	+	+	+	+	+	+	+	+	+	1	1	r	+	1	+		1	1	+	+		1
Pentaschistis curvifolia	+	+	2	+	+	1	2	2	2	+	+		2	2	1	1	1	2	1	2	2	1		2
Ursinia nudicaulis		1	+	2	2	+	+	+	+	2	2	+	+	+	+	2	+	1	2		1	3		1
Cliffortia ruscifolia	+	2	+	2	+	+		r	+	+		+		1	+			r		2		r		
Ehrharta ramosa subsp. aphylla	1	1	1	+	1	1	+	+	+	+			+	2	1	+	2	+	2	1	1	1		r
Elegia ebracteata	1	+	1	+	+	+	+	+	+			+	1	2	1	+	1	+	+	2	2	+		+
Thamnochortus nutans	r	1	+										+	1	+		+		+	2	1			
Erica plukenetii	r	r	r		1	+	r	+					+	+	+		+	+	1	1	+			2
Crassula coccinea	2	2	+	1		2	3			2	2	2	2	+	+	2	1		3		2	2		3
Lampranthus falciformis	2	+		2	1					2	+	1	2			2	2			3	3	2		1
Hypochaeris radicata	+			+	1	1		1	2	+	+	1	2		2	2	2	2	1	2	2	2		1
Disa bracteata	2				r		r	r	+	+	+		r									r		
Restio bifidus									2	+	+					2					2	+		
Euryops abrotanifolius	+			r			+		+	+	1					+		+	+		2	1		
Pentaschistis tortuosa	r	+			+	+		2	2				r	+				r	+	+	2			r
Penaea mucronata	r	+			r				r			r												
Erica ericoides	r	r		+							r					+	+		+	r	+			r
Tritoniopsis unguiculatus	+			+								+	+							+	1			1
Ehrharta setacea subsp. setacea																								
Hymenolepis parviflora																								
Erica hispidula																								
Moss																			2	2				
Number of species	**18**	**15**	**11**	**14**	**14**	**12**	**11**	**12**	**14**	**13**	**12**	**11**	**15**	**12**	**12**	**13**	**13**	**11**	**15**	**15**	**16**	**13**		**14**

	1988 relevés												2005 relevés											
Species	**7**	**3**	**1**	**10**	**9**	**2**	**4**	**6**	**5**	**12**	**11**	**8**	**7**	**3**	**1**	**10**	**9**	**2**	**4**	**6**	**5**	**12**	**11**	**8**
Restio perplexus	2			+	1			1	3	+	2	1			1					1				+
Anthospermum aethiopicum	2	+	+	+	+	1		1	1	+		+	1		+		1		1	+	+	r	r	r
Chrysitrix capensis	+								1	r												+		+
Pentaschistis curvifolia	+												2			+	r		1	+	1	r	r	+
Ursinia nudicaulis	+	+	+		+		+		+		+	+												1
Cliffortia ruscifolia	1	1	1	2	1	2	1		1	2	+	+	+		2	+	2		2	+	1	+	+	r
Ehrharta ramosa subsp. aphylla	1	1	+	+	1	1	1	1	1	r	+	1	2		+		1		2	2	2		r	
Elegia ebracteata	1	1	1	2	1	1	2	+	2	1	2				+	2	1		1	r	1	2	2	3
Thamnochortus nutans	2			2	2	1	1	2	2	2	1	1	1			1	1			+		1	1	1
Erica plukenetii	1	2	1		1	1	1	1	1			1	1		2		1		2			r		+
Crassula coccinea	+		r				1		+				r		+		+		1	1	+			
Lampranthus falciformis	+	r	r		+	+	r	1	+			+	+		+	r	r		1	1	+			r
Hypochaeris radicata		+	+				1		+			r	+		1				1	1				r
Disa bracteata													r		r	+	r			+	r			r
Restio bifidus			1			+			1				2			+	+						+	2
Euryops abrotanifolius													r				1		r		r	r		r
Pentaschistis tortuosa	+		r		+		+	+	+	+	1	+	r								+			
Penaea mucronata				+					+	1	+	1				+						+	+	
Erica ericoides													+				1			1				1
Tritoniopsis unguiculatus																								
Ehrharta setacea subsp. setacea																r						+	1	
Hymenolepis parviflora		+	1				+						r		r					r				
Erica hispidula				2	+					2	2	+	+			2			1			3	2	2
Moss																								
Number of species	**13**	**9**	**12**	**8**	**11**	**8**	**11**	**8**	**15**	**10**	**9**	**12**	**16**	**0**	**11**	**10**	**13**	**0**	**11**	**13**	**10**	**11**	**10**	**16**

	2010 relevés											
Species	**7**	**3**	**1**	**10**	**9**	**2**	**4**	**6**	**5**	**12**	**11**	**8**
Restio perplexus			1					2				+
Anthospermum aethiopicum	1		1		+		+	1	1	+		+
Chrysitrix capensis									+			
Pentaschistis curvifolia	2						1		1			
Ursinia nudicaulis												2
Cliffortia ruscifolia	1		2	1	2		2	2	2	+	+	+
Ehrharta ramosa subsp. aphylla	2		2		1			1	2	r	1	
Elegia ebracteata	2		1	2	+		2	+	r	2	3	3
Thamnochortus nutans	+			1	+		r	+		1	1	+
Erica plukenetii	1		2		+		3	1	2	r		r
Crassula coccinea	r		1				+	r	+			r
Lampranthus falciformis			1	r	1		+	+	r			r
Hypochaeris radicata	r		1				1	1	1			
Disa bracteata	r		r						r			r
Restio bifidus	2			r	+				+	+	1	1
Euryops abrotanifolius					r				r	r		+
Pentaschistis tortuosa	+				r			+				
Penaea mucronata				+						+	r	
Erica ericoides					1							
Tritoniopsis unguiculatus				+			r	r		r	+	
Ehrharta setacea subsp. setacea				r			1		r		+	
Hymenolepis parviflora	+		+					r				
Erica hispidula	+			2	2		+		r	3	2	1
Moss							2	2	2			
Number of species	**14**	**0**	**11**	**9**	**12**	**0**	**13**	**14**	**16**	**11**	**9**	**13**

APPENDIX B: Species omitted from the 1977, 1985, 1988, 2005 and 2010 sampling periods

Field label (2010)	*Species No.*	*Original field name*	*year*	*Fate of species*	*cover abundance value*	*Notes*
		3 Cliffortia aristata	*1985*	*Removed*	*5 = 1*	
		Agnostis sp. (bergiana?)	*1988*	*Removed*	*3 = +*	
		Babiana sp.	*1988*	*Removed*	*2 = r; 3 = r; 11 = +*	
	25	*Centella caespitosa*	*2005*	*Removed*	*6 = r*	
WTM/71		*Centella caespitosa*	*2010*	*Removed*	*12 = r*	
		Chironia baccifera	*2005*	*Removed*	*4 = r; 5 = r*	
WTM/20		*Chironia baccifera*	*2010*	*Removed*	*5 = r*	
		Chrysanthemoides monilifera	*1988*	*Removed*	*6 = r*	
		Cliffortia atrata	*1977*	*Removed*	*5 = +*	
	46	*Crassula campestris*	*2005*	*Removed*	*1 = r*	
WTM/47		*Drosera trinervia*	*2010*	*Removed*	*7 = r*	
		Erica	*2010*	*Removed*	*4 = r; 6 = r*	
		Erica coccinea	*1988/2010*	*Removed*	*(1988) 1 = +; 3 = 1; 7 = + (2010) 12 = r*	
	76	*Erica ericifolia*	*2005*	*Removed*	*9 = +; 5 = r*	
		Erica lutea	*2010*	*Removed*	*1 = r*	
		Erigeron canadensis	*1988*	*Removed*	*3 = r; 4 = r*	
	48	*Gibbaria ilicifolia*	*2005*	*Removed*	*12 = r*	
	88	*Grass sp. C*	*2005*	*Removed*	*1 = r*	
	23	*Harveya tubulosa*	*1977*	*Removed*	*7 = r; 10 = r*	
WTM/59		*Hebenstretia*	*2010*	*Removed*	*5 = r*	
	69	*Helichrysum. cf. cylindriflorum*	*2005*	*Removed*	*12 = r*	
	62	*Holothrix villosa*	*2005*	*Removed*	*1 = r; 8 = r*	
	90	*Lachenalia sp.*	*2005*	*Removed*	*12 = r*	
WTM/66		*Mairia crenata*	*2010*	*Removed*	*12 = r*	
		Helichrysum sp.	*2005*	*Removed*	*5 = r*	
	37	*No name*	*1985*	*Removed*	*6 = r*	
	33	*No name*	*1985*	*Removed*	*3 = r*	

WTM/29		*Othonna arborescens*	*2010*	*Removed*	*6 = r; 7 = r*
		Pelargonium sp.	*1977*	*Removed*	*6 = r*
		Pentaschistis curvifolia	*2010*	*Removed*	*9 = r*
WTM/58/56		*Pentaschistis melouinensis*	*2005 & 2010*	*Removed*	*(2005) 5 = r; 11 = r; 12 = + (2010) 1 = +; 4 = +; 6 = +; 7 = 2; 8 = +; 9 = +; 10 = +; 11 = r; 12 = +*
		red flower (1977)	*1977*	*Removed*	*12 = r*
WTM/64		*Satyrium sp.*	*2010*	*Removed*	*8 = r; 11 = r*
WTM/73		*Satyrium sp.*	*2010*	*Removed*	*4 = r; 8 = r; 11 = r*
WTM/12		*Searsia lucida*	*2010*	*Removed*	*4 = r; 6 = r*
		small plant (1977)	*1977*	*Removed*	*12 = r*
WTM/68		*Tetraria cf. capillacea*	*2010*	*Removed*	*10 = r*
	50	*Trifolium filiforme*	*1985*	*Removed*	*(1985) 1 = r; (2005) 1 = +*
		Unidentified geophyte	*2010*	*Removed*	*5 = r; 10 = r; 12 = r*
	85	*Unidentified sp. C*	*2005*	*Removed*	*10 = r*
		Unknown composite (1985)	*1985*	*Removed*	*5 = r*
		Unknown monocot	*1985*	*Removed*	*1 = r*
		Unknown Poaceae	*1985*	*Removed*	*1 = r*
WTM/34		*Utricularia capensis*	*2010*	*Removed*	*8 = r*
	79	*Weed sp. A*	*2005*	*Removed*	*1 = r*
	59	*Rhus laevigata (= Searsia lucida)*	*2005*	*Removed*	

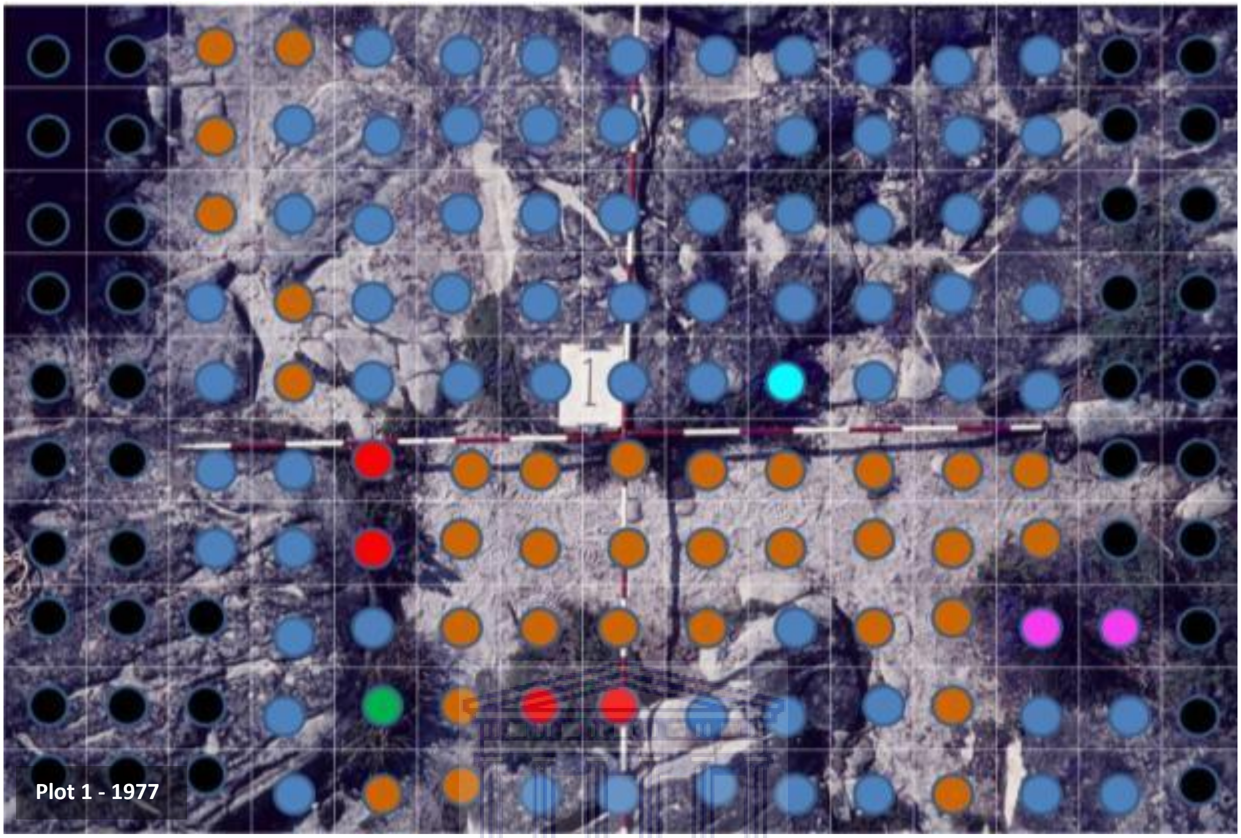
APPENDIX C: Species name changes from the 1977, 1985, 1988, 2005 and 2010 sampling periods

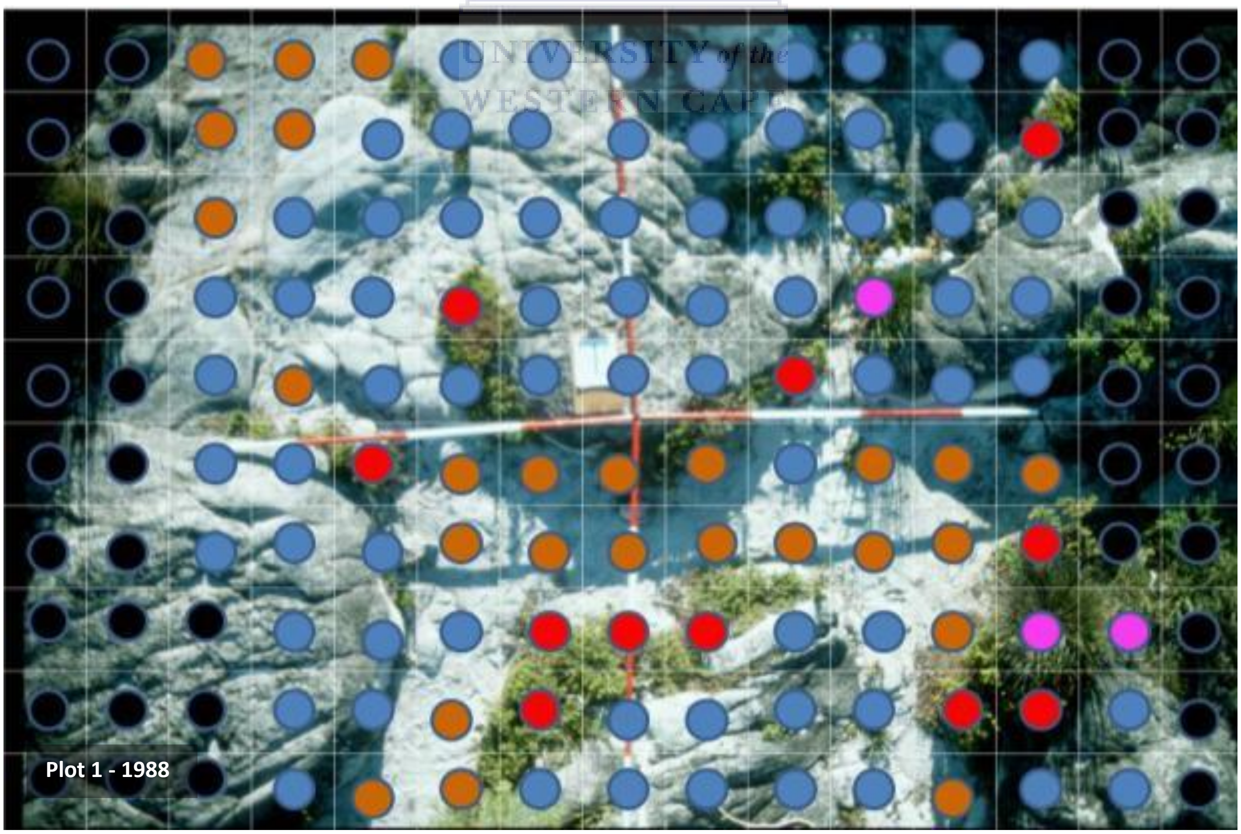
Field label (2010)	*Species No.*	*Original field name*	*Year of record*	*Name changed to*	*relevé & cover abundance value*	*Notes*
WTM/25 & WTM/62		*Pentaschistis curvifolia*	*2010*	*No name change*	*4 =1; 5 = 1; 7 = 2*	*Species added from field notes*
	63	*Anthospermum galioides subsp. galioides*	*2005/2010*	*Anthospermum aethiopicum*		
		Bulbinella sp.	*1988*	*Bulbine allooides*		
	71	*Ficinia sp.*	*2005*	*Chrysitrix capensis*	*8 = +*	
		Cliffortia ruscifolia (new)1988	*1988*	*Cliffortia ruscifolia*	*2 = 1; 3 = 1*	*for both Cliffortia ruscifolia (new)1988 & Cliffortia ruscifolia (old)1988 cover combined = 2*
		Cliffortia ruscifolia (old)1988	*1988*	*Cliffortia ruscifolia*		
		Monadenia micrantha	*1977/1985/ 1988*	*Disa bracteata*		
		Helipterum sp.	*1988*	*Edmondia sesamoides*	*11 = +; 12 = r*	
WTM/21		*Pentaschistis ramosa subsp. aphylla*	*2010*	*Ehrharta ramosa subsp. aphylla*		
	4	*Ehrharta ramosa*	*1977/1985/ 1988*	*Ehrharta ramosa subsp. aphylla*		
	81	*Erica (2005)*	*2005*	*Erica sp. (2010)*	*5 = +*	
	22	*Euryops sp.*	*1977/1988*	*Euryops abrotanifolius*	*(1988) 4 = +; 5 = +; 11 = 1; 12 = + (1985) 2 = +; 4 = +; 10 = +; 12 = 1*	
	18	*Leontonyx sp.*	*1977/1985*	*Helichrysum leontonyx*		
	67	*Helichrysum sp.? capitellum*	*2005*	*Helichrysum odoratissimum*	*7 = r*	
		Pentaschistis pallens	*2005*	*Pentaschistis tortuosa*	*5 = +; 7 = r*	
	30 (2005)	*Pentaschistis rigidissima*	*2005*	*Pentaschistis curvifolia*	*(2005) 4 =1; 5 =1; 6 = +; 6 = 2; 7 = +;8 = +; 9 = r; 10 = +; 11 = r; 12 = r*	
		Pentaschistis pallescens	*1977 & 1985 & 1988*	*Pentaschistis curvifolia*		*All plots (1977/1985/1988) moved*
	80	*Grass sp. A*	*2005*	*Pentaschistis malouinensis*	*5 = r; 11 = r; 12 = +*	
	20	*Pentameris sp.*	*1977/1985*	*Pentaschistis rigidissima*	*(1977) 2 = +; 6 = +; 7 = r; 8 = + (1985) 2 = r; 3 = +; 4 = +; 5 = 2; 6 = +; 7 = r; 8 = r*	
		Pentaschistis rigidissima	*1977 & 1985 & 1988*	*Pentaschistis tortuosa*		*All plots (1977/1985/1988) moved*

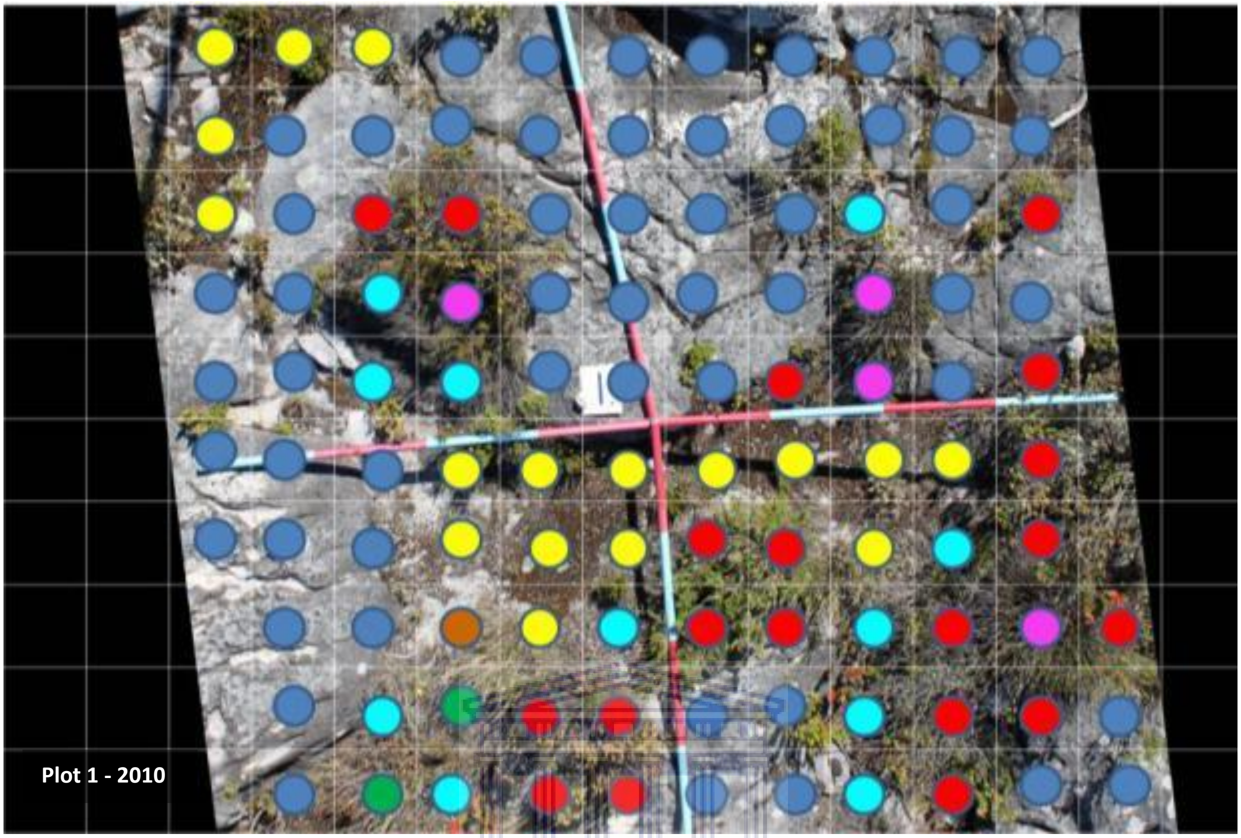
WTM/61		*Grass 'shiny'*	*2010*	*Pentaschistis tortuosa*	*6 = r; 7 = r; 9 = +*
		Ischyrolepis sp.	*1977/1985/ 1988*	*Restio bifidus*	*(1977) 5 = 2; 11 = r; 12 = r; (1985) 5 = 2; 10 = 2; 12 = +; (1988) 1 = 1; 2 = +; 5 = 1*
	89	*Tetraria sp.*	*2005*	*Tetraria cuspidata*	*11 = +*
WTM/17		*Thamnochortus nutans (female)*	*2010*	*Thamnochortus nutans*	
WTM/15		*Thamnochortus nutans (male)*	*2010*	*Thamnochortus nutans*	
WTM/35		*Thesium cf. strictum*	*2010*	*Thesium strictum*	*8 = +*
	21	*Tritoniopsis sp.*	*1977/1985*	*Tritoniopsis unguiculatus*	
	68	*Helichrysum. sp? spathulatum*	*2005*	*Vallereophyton dealbatum*	*7 = r; 8 = r*

Appendix D: Photographic analysis based on transition matrices and categorization of cover of low level imagery: comparing plots between 1977 and 2010 sampling periods (Coley, 1977, Emms, 2010).

- rock
- ericoid & succulent shrubs
- restioid
- litter and free-standing dead material
- moss
- sand
- graminoid
- incomparable


Plot 1 - 1977


Plot 1 - 1988


Plot 1 - 2010

Cell Totals

Plot 1

		1988									
		Rock	Sand	Restioid	Ericoid	Graminoid	Moss	Litter & dead material	Total 1977	Calculated %cover	Estimated %cover
	Rock	63	2	1	3	0	0	0	69	63	68
	Sand	4	24	0	5	0	0	0	33	30	27
	Restioid	0	0	2	0	0	0	0	2	2	1
1977	Ericoid	2	0	0	2	0	0	0	4	4	3
	Graminoid	1	0	0	0	0	0	0	1	1	0
	Moss	0	0	0	0	0	0	0	0	0	0
	Litter & dead material	0	0	0	1	0	0	0	1	1	1
	Total 1988	70	26	3	11	0	0	0	**110**		
	Calculated %cover	64	24	3	10	0	0	0			
	Estimated %cover	67	25	2	5	0	0	1			

Transition Matrix

		1988							
		Rock	Sand	Restioid	Ericoid	Graminoid	Moss	Litter & dead material	
	Rock	0.913	0.029	0.014	0.043	0.000	0.000	0.000	1
	Sand	0.121	0.727	0.000	0.152	0.000	0.000	0.000	1
	Restioid	0.000	0.000	1.000	0.000	0.000	0.000	0.000	1
1977	Ericoid	0.500	0.000	0.000	0.500	0.000	0.000	0.000	1
	Graminoid	1.000	0.000	0.000	0.000	0.000	0.000	0.000	1
	Moss	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0
	Litter & dead material	0.000	0.000	0.000	1.000	0.000	0.000	0.000	1

Cell Totals

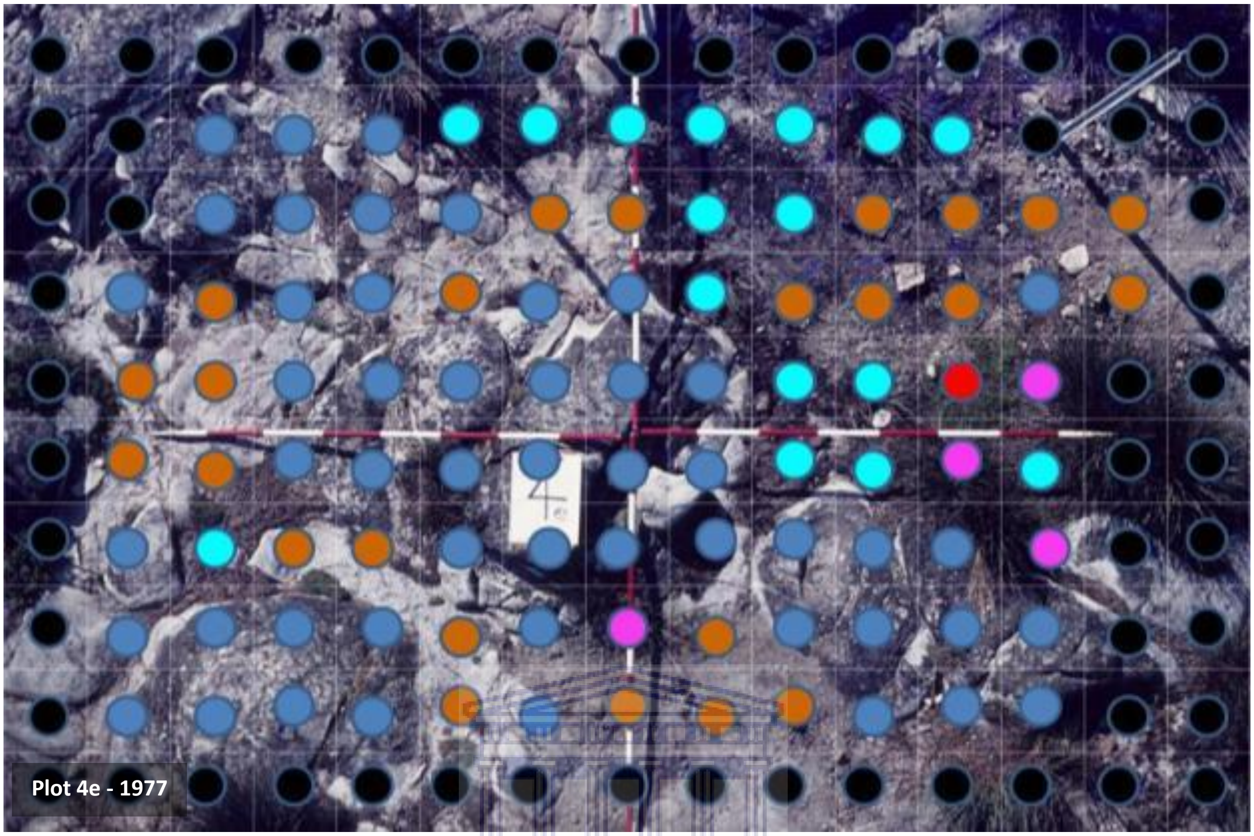
Plot 1

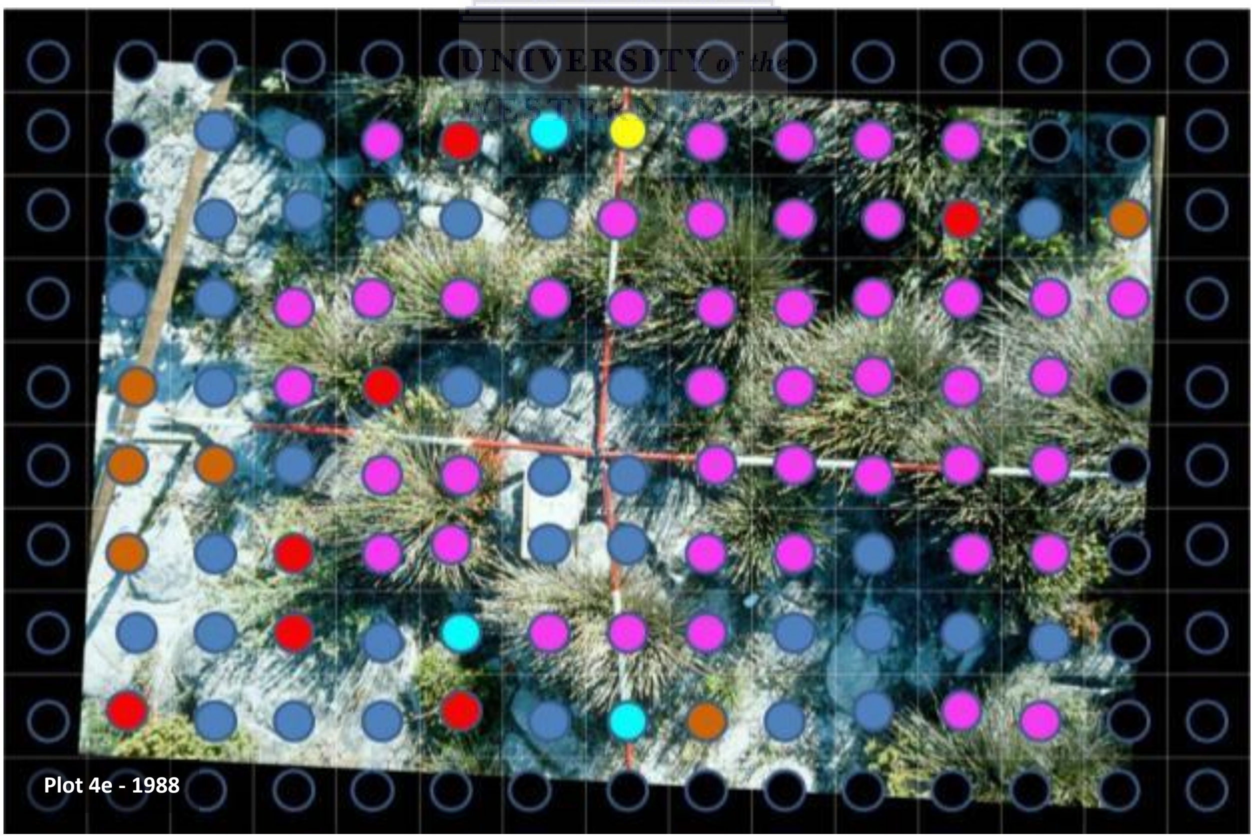
		2010									
		Rock	Sand	Restioid	Ericoid	Graminoid	Moss	Litter & dead material	Total 1988	Calculated %cover	Estimated %cover
	Rock	51	1	1	9	0	1	8	70	64	67
	Sand	2	0	0	4	2	15	2	26	24	25
	Restioid	0	0	2	1	0	0	0	3	3	2
1988	Ericoid	2	0	1	6	0	1	1	11	10	5
	Graminoid	0	0	0	0	0	0	0	0	0	0
	Moss	0	0	0	0	0	0	0	0	0	0

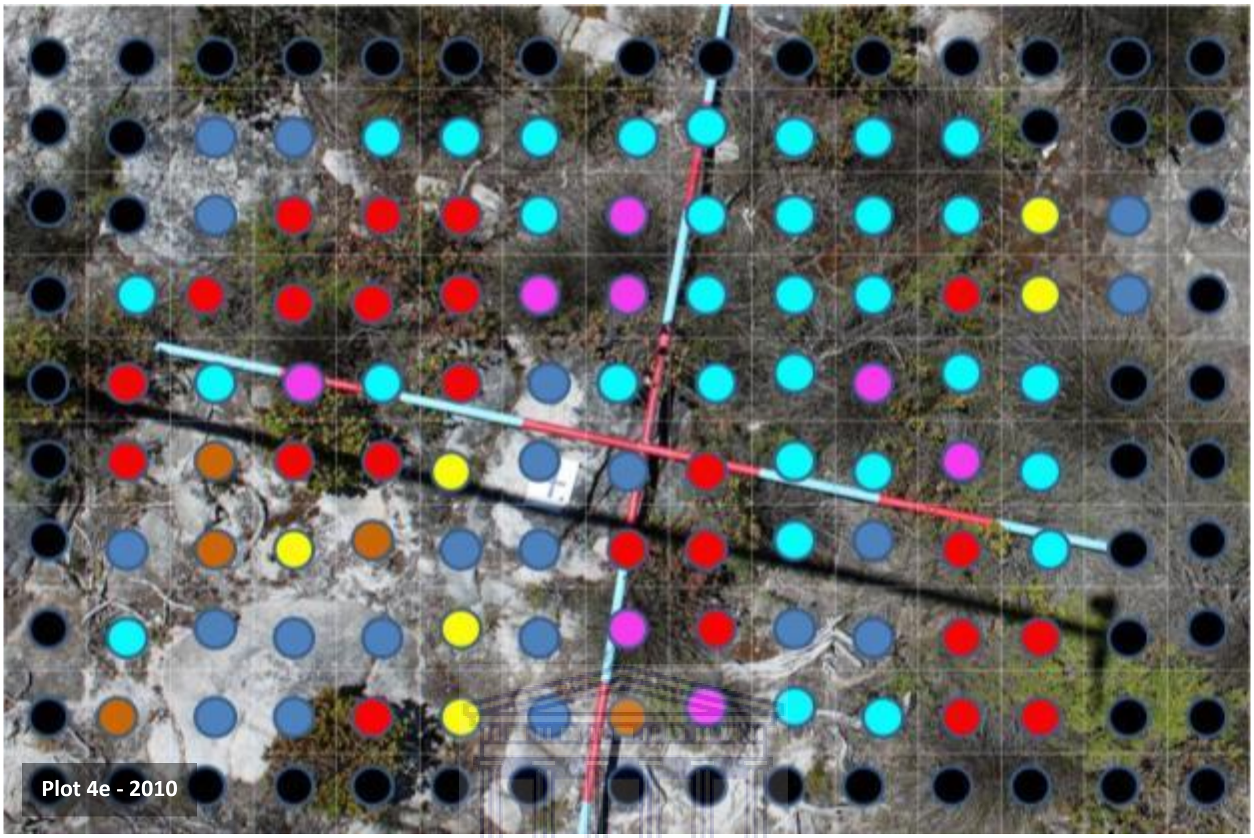
Litter & dead material	0	0	0	0	0	0	0	0	0	1
Total 2010	55	1	4	20	2	17	11	**110**		
Calculated %cover	50	1	4	18	2	15	10			
Estimated %cover	60	2	4	15	3	13	3			

Transition Matrix

				2010					
		Rock	Sand	Restioid	Ericoid	Graminoid	Moss	Litter & dead material	
	Rock	0.729	0.014	0.014	0.129	0.000	0.014	0.114	1
	Sand	0.077	0.000	0.000	0.154	0.077	0.577	0.077	1
	Restioid	0.000	0.000	0.667	0.333	0.000	0.000	0.000	1
1988	Ericoid & other	0.182	0.000	0.091	0.545	0.000	0.091	0.091	1
	Graminoid	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0
	Moss	0.000	0	0	0	0	0	0	0
	Litter & dead material	0.000	0	0	0		0	0	0


Plot 4e - 1977


Plot 4e - 1988


Plot 4e - 2010

Cell Totals

Plot 4

		Rock	Sand	Restioid	Ericoid	Graminoid	Moss	Litter & dead material	Total 1977	Calculated %cover	Estimated %cover
		1988									
	Rock	28	1	18	3	0	0	0	50	53	53
	Sand	5	5	9	3	0	0	2	24	25	40
	Restioid	0	0	4	0	0	0	0	4	4	3
1977	Ericoid	0	0	1	0	0	0	0	1	1	1
	Graminoid	0	0	0	0	0	0	0	0	0	0
	Moss	0	0	0	0	0	0	0	0	0	0
	Litter & dead material	1	0	12	1	0	1	1	16	17	3
	Total 1988	34	6	44	7	0	1	3	**95**		
	Calculated %cover	36	6	46	7	0	1	3			
	Estimated %cover	36	6	46	7	0	1	3			

Transition Matrix

		Rock	Sand	Restioid	Ericoid	Graminoid	Moss	Litter & dead material	
				1988					
	Rock	0.560	0.020	0.360	0.060	0.000	0.000	0.000	1
	Sand	0.208	0.208	0.375	0.125	0.000	0.000	0.083	1
	Restioid	0.000	0.000	1.000	0.000	0.000	0.000	0.000	1
1977	Ericoid	0.000	0.000	1.000	0.000	0.000	0.000	0.000	1
	Graminoid	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0
	Moss	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0
	Litter & dead material	0.063	0.000	0.750	0.063	0.000	0.063	0.063	1

Cell Totals

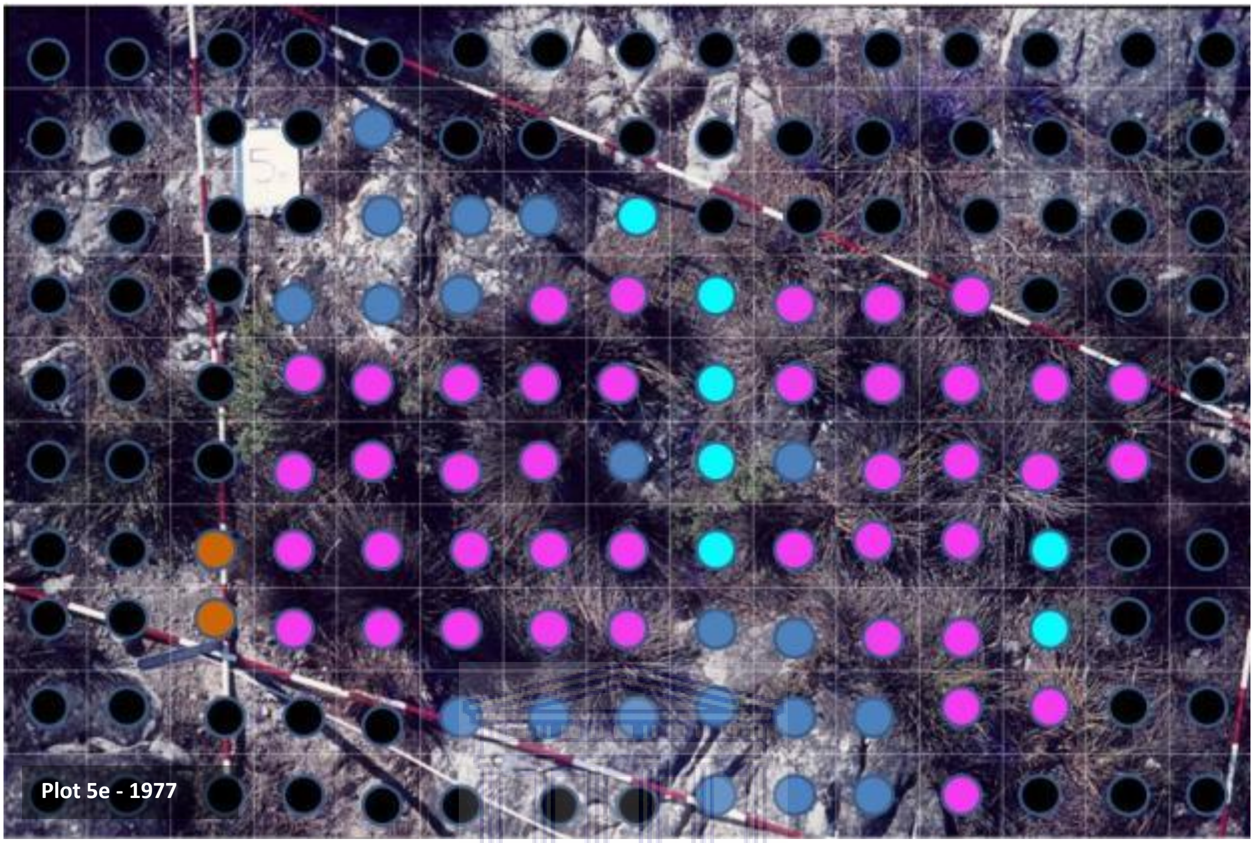
Plot 4

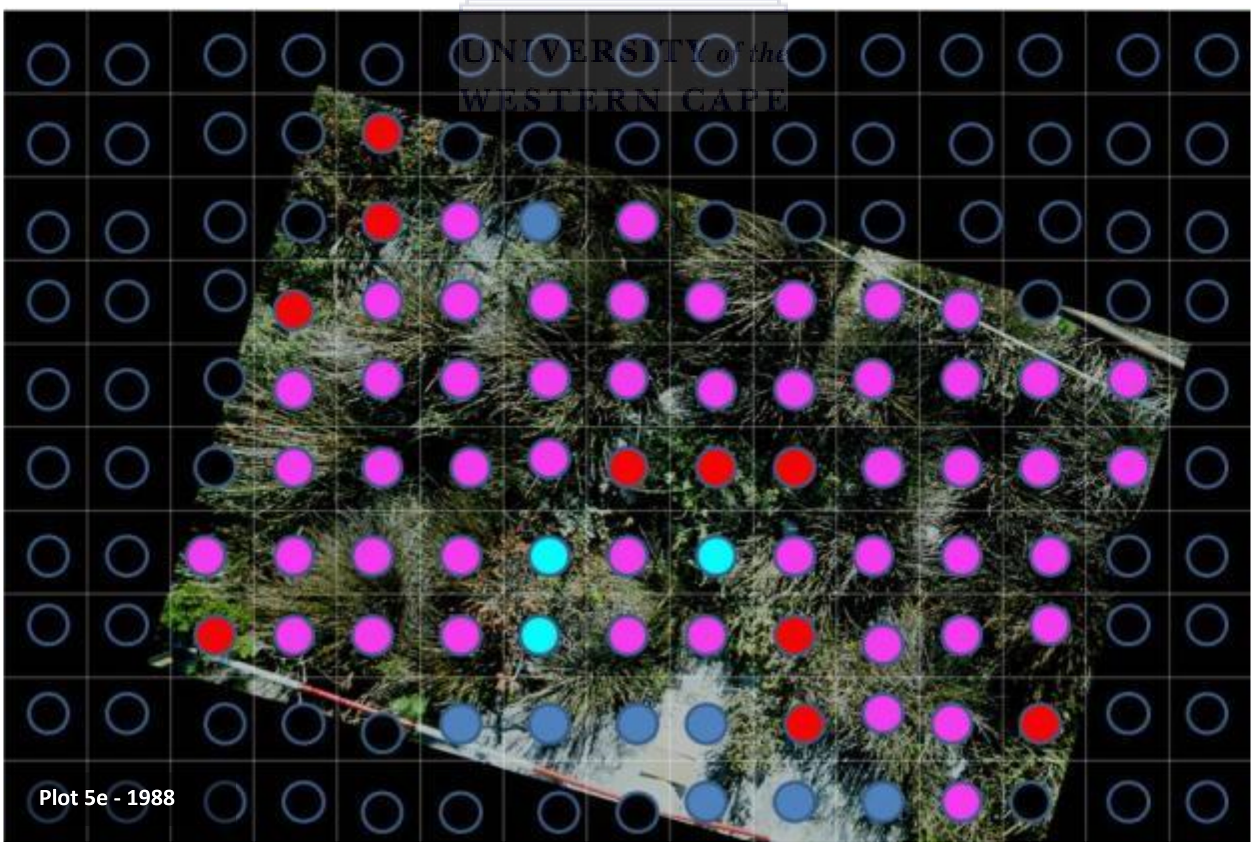
		Rock	Sand	Restioid	Ericoid	Graminoid	Moss	Litter & dead material	Total 1988	Calculated %cover	Estimated %cover
					2010						
	Rock	15	1	0	10	0	1	7	34	36	42
	Sand	2	1	1	2	0	0	0	6	6	5
	Restioid	3	1	7	12	0	1	20	44	46	40
1988	Ericoid	1	1	0	0	0	2	3	7	7	2
	Graminoid	0	0	0	0	0	0	0	0	0	0
	Moss	0	0	0	0	0	0	1	1	1	1

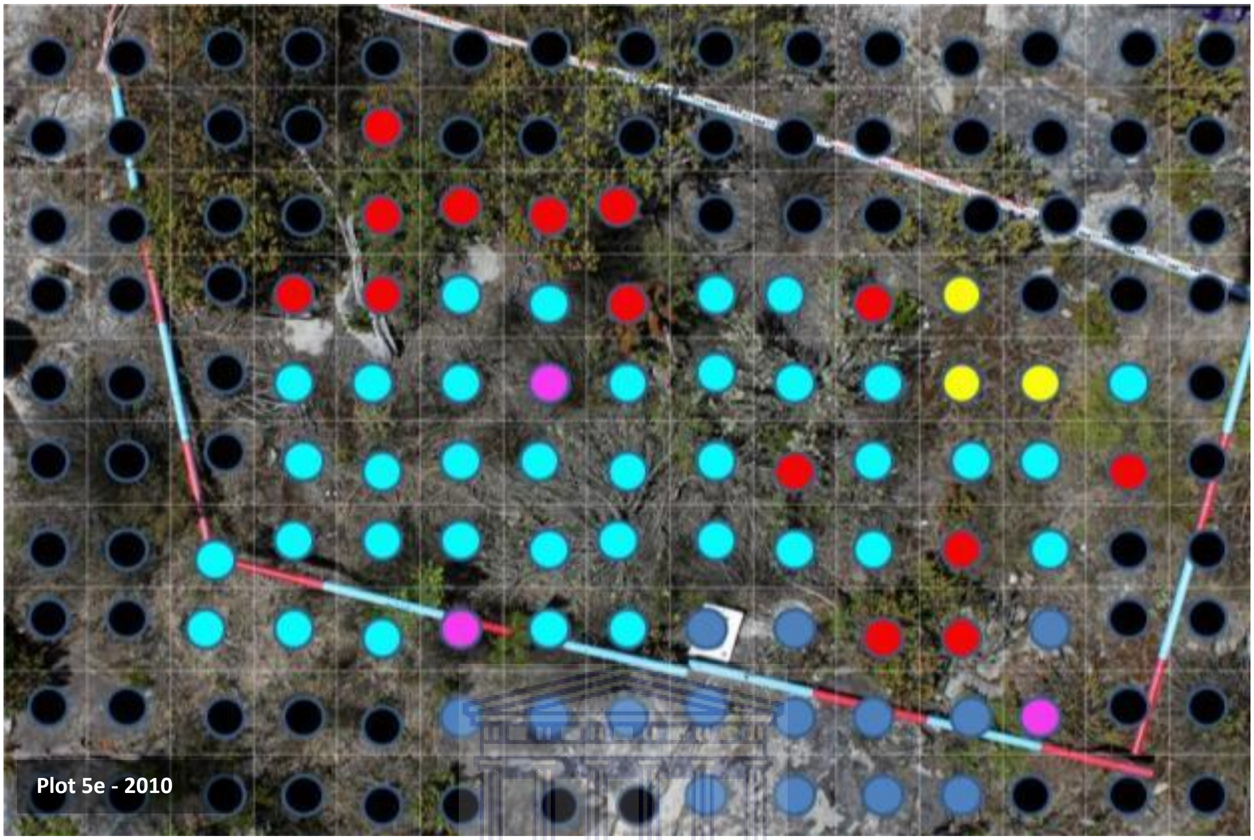
Litter & dead material	0	1	0	0	0	1	1	3	3	10
Total 2010	21	5	8	24	0	5	32	**95**		
Calculated %cover	22	5	8	25	0	5	34			
Estimated %cover	25	4	18	20	0	13	20			

Transition Matrix

				2010					
		Rock	Sand	Restioid	Ericoid	Graminoid	Moss	Litter & dead material	
	Rock	0.441	0.029	0.000	0.294	0.000	0.029	0.206	1
	Sand	0.333	0.167	0.167	0.333	0.000	0.000	0.000	1
	Restioid	0.068	0.023	0.159	0.273	0.000	0.023	0.455	1
1988	Ericoid & other	0.143	0.143	0.000	0.000	0.000	0.286	0.429	1
	Graminoid	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0
	Moss	0.000	0	0	0	0	0	0	0
	Litter & dead material	0.000	0	0	0		0	0	0


Plot 5e - 1977


Plot 5e - 1988


Plot 5e - 2010

Cell Totals

Plot 5

		1988									
		Rock	Sand	Restioid	Ericoid	Graminoid	Moss	Litter & dead material	Total 1977	Calculated %cover	Estimated %cover
	Rock	8	0	5	7	0	0	0	20	29	20
	Sand	0	0	1	1	0	0	0	2	3	0
	Restioid	0	1	38	1	0	0	2	42	60	30
1977	Ericoid	0	0	0	0	0	0	0	0	0	1
	Graminoid	0	0	0	0	0	0	0	0	0	0
	Moss	0	0	0	0	0	0	0	0	0	0
	Litter & dead material	0	0	5	1	0	0	0	6	9	30
	Total 1988	8	1	49	10	0	0	2	**70**		
	Calculated %cover	11	1	70	14	0	0	3			
	Estimated %cover	11	0	69	16	0	0	4			

Transition Matrix

				1988					
		Rock	Sand	Restioid	Ericoid	Graminoid	Moss	Litter & dead material	
	Rock	0.400	0.000	0.250	0.350	0.000	0.000	0.000	1
	Sand	0.000	0.000	0.500	0.500	0.000	0.000	0.000	1
	Restioid	0.000	0.024	0.905	0.024	0.000	0.000	0.048	1
1977	Ericoid	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
	Graminoid	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0
	Moss	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0
	Litter & dead material	0.000	0.000	0.833	0.167	0.000	0.000	0.000	1

Cell Totals

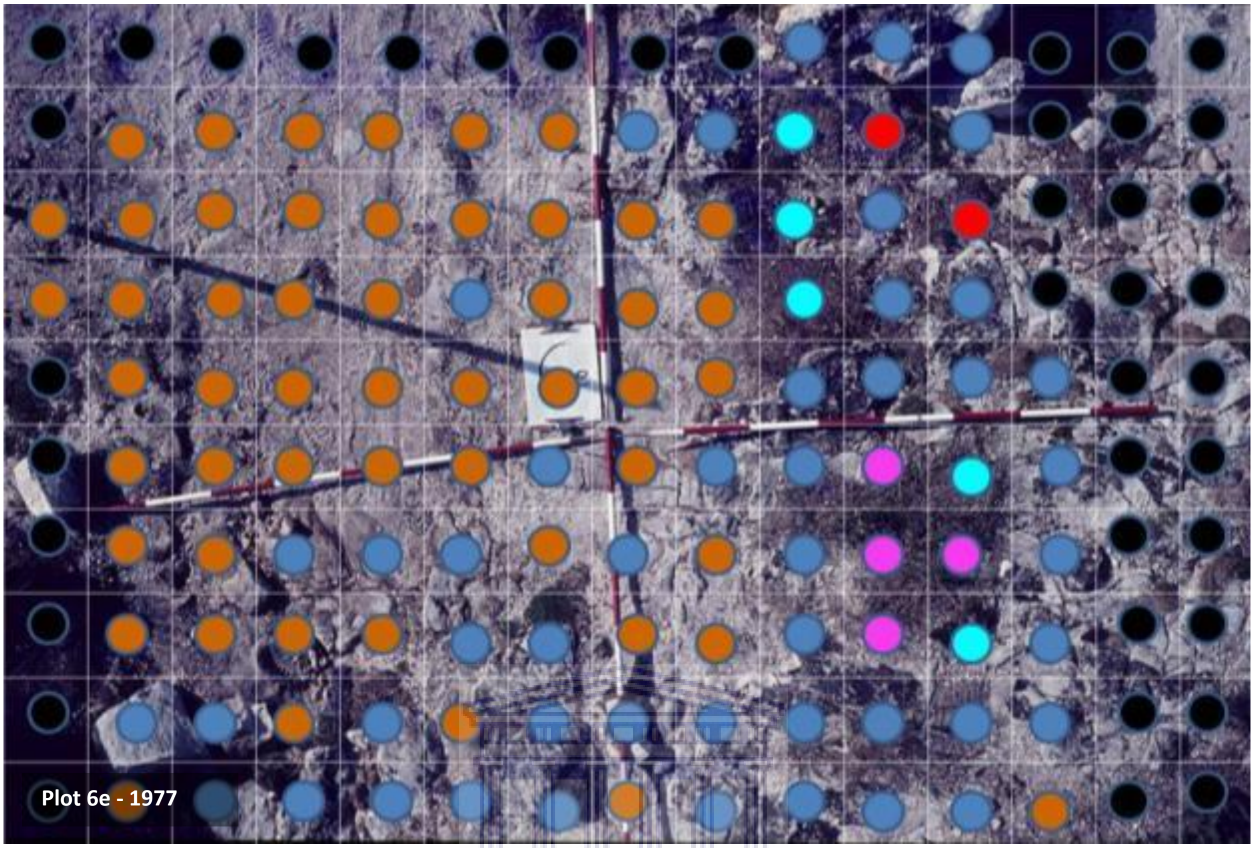
Plot 5

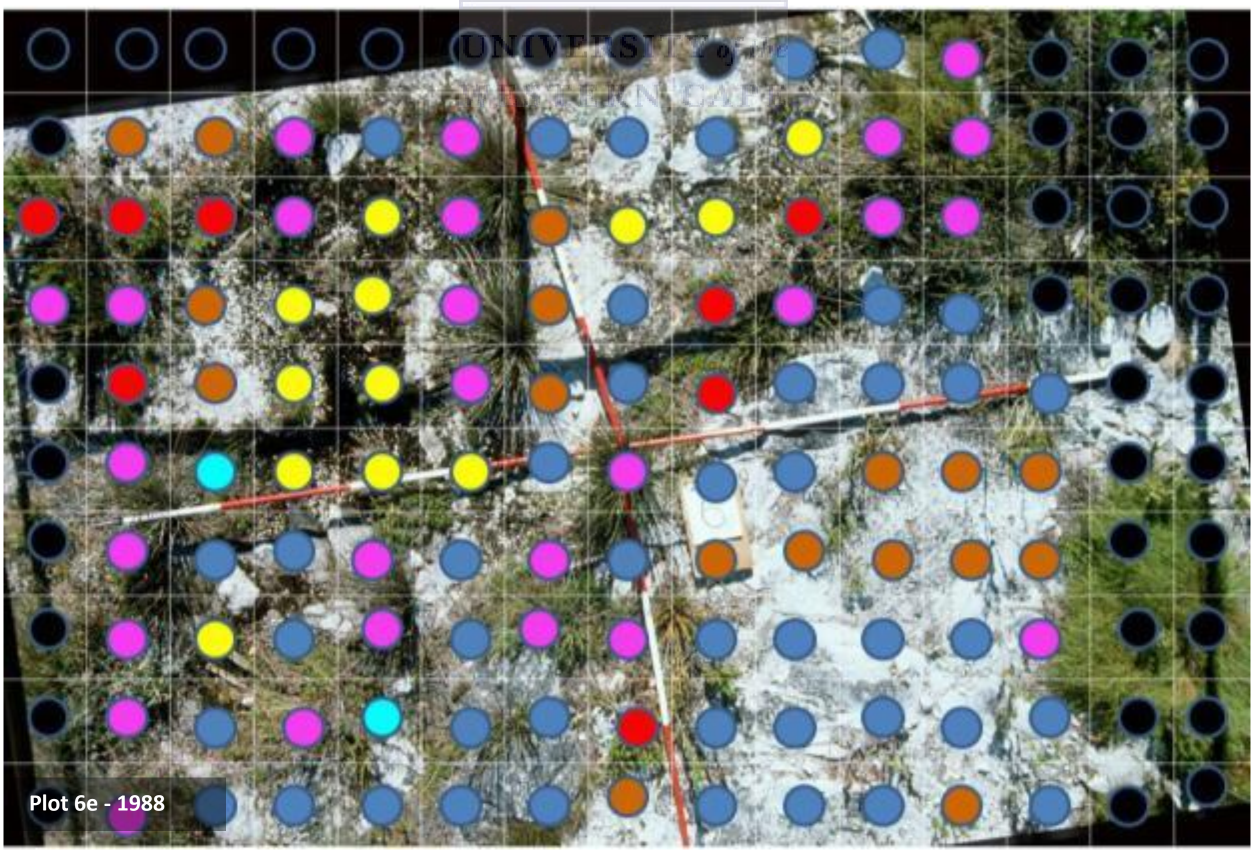
		2010									
		Rock	Sand	Restioid	Ericoid	Graminoid	Moss	Litter & dead material	Total 1988	Calculated %cover	Estimated %cover
	Rock	7	0	0	1	0	0	0	8	11	7
	Sand	0	0	0	0	0	0	0	0	0	0
	Restioid	4	0	2	9	0	3	30	48	69	80
1988	Ericoid	3	0	1	4	0	0	3	11	16	6
	Graminoid	0	0	0	0	0	0	0	0	0	0
	Moss	0	0	0	0	0	0	0	0	0	0

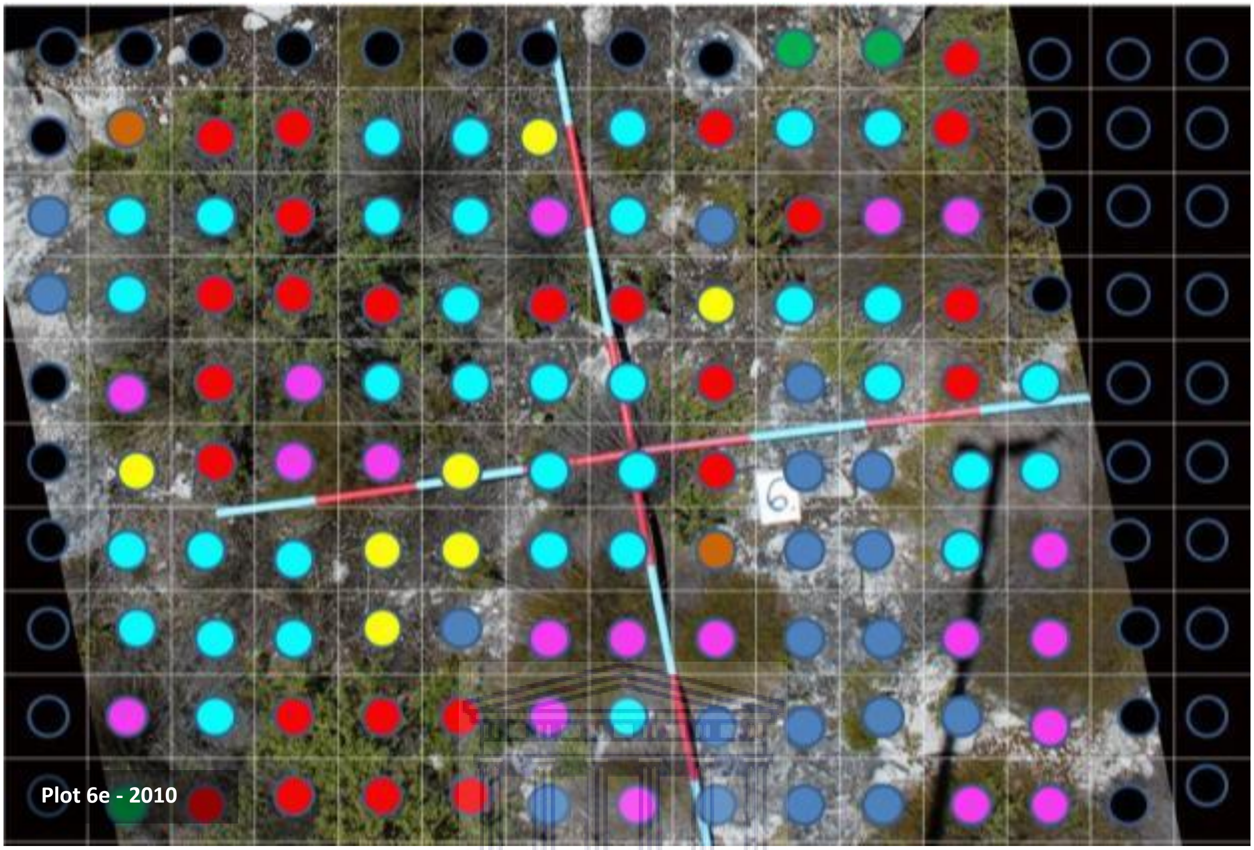
Litter & dead material	0	0	0	0	0	0	3	3	4	7
Total 2010	14	0	3	14	0	3	36	**70**		
Calculated %cover	20	0	4	20	0	4	51			
Estimated %cover	6	0	5	17	0	7	65			

Transition Matrix

				2010					
		Rock	Sand	Restioid	Ericoid	Graminoid	Moss	Litter & dead material	
	Rock	0.875	0.000	0.000	0.125	0.000	0.000	0.000	1
	Sand	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0
	Restioid	0.083	0.000	0.042	0.188	0.000	0.063	0.625	1
1988	Ericoid & other	0.273	0.000	0.091	0.364	0.000	0.000	0.273	1
	Graminoid	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0
	Moss	0.000	0	0	0	0	0	0	0
	Litter & dead material	0.000	0	0	0		0	0	0


Plot 6e - 1977


Plot 6e - 1988


Plot 6e - 2010

Plot 6

		1988									
		Rock	Sand	Restioid	Ericoid	Graminoid	Moss	Litter & dead material	Total 1977	Calculated %cover	Estimated %cover
	Rock	33	4	8	1	0	0	1	47	43	55
	Sand	9	9	16	6	0	11	1	52	47	40
	Restioid	1	3	0	0	0	0	0	4	4	1
1977	Ericoid	0	0	2	0	0	0	0	2	2	0
	Graminoid	0	0	0	0	0	0	0	0	0	0
	Moss	0	0	0	0	0	0	0	0	0	0
	Litter & dead material	1	1	1	1	0	1	0	5	5	4
	Total 1988	44	17	27	8	0	12	2	**110**		
	Calculated %cover	40	15	25	7	0	11	2			
	Estimated %cover	40	15	25	7	0	11	2			

Transition Matrix

		1988							
		Rock	Sand	Restioid	Ericoid	Graminoid	Moss	Litter & dead material	
	Rock	0.702	0.085	0.170	0.021	0.000	0.000	0.021	1
	Sand	0.173	0.173	0.308	0.115	0.000	0.212	0.019	1
	Restioid	0.250	0.750	0.000	0.000	0.000	0.000	0.000	1
1977	Ericoid	0.000	0.000	1.000	0.000	0.000	0.000	0.000	1
	Graminoid	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0
	Moss	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0
	Litter & dead material	0.200	0.200	0.200	0.200	0.000	0.200	0.000	1

Cell Totals

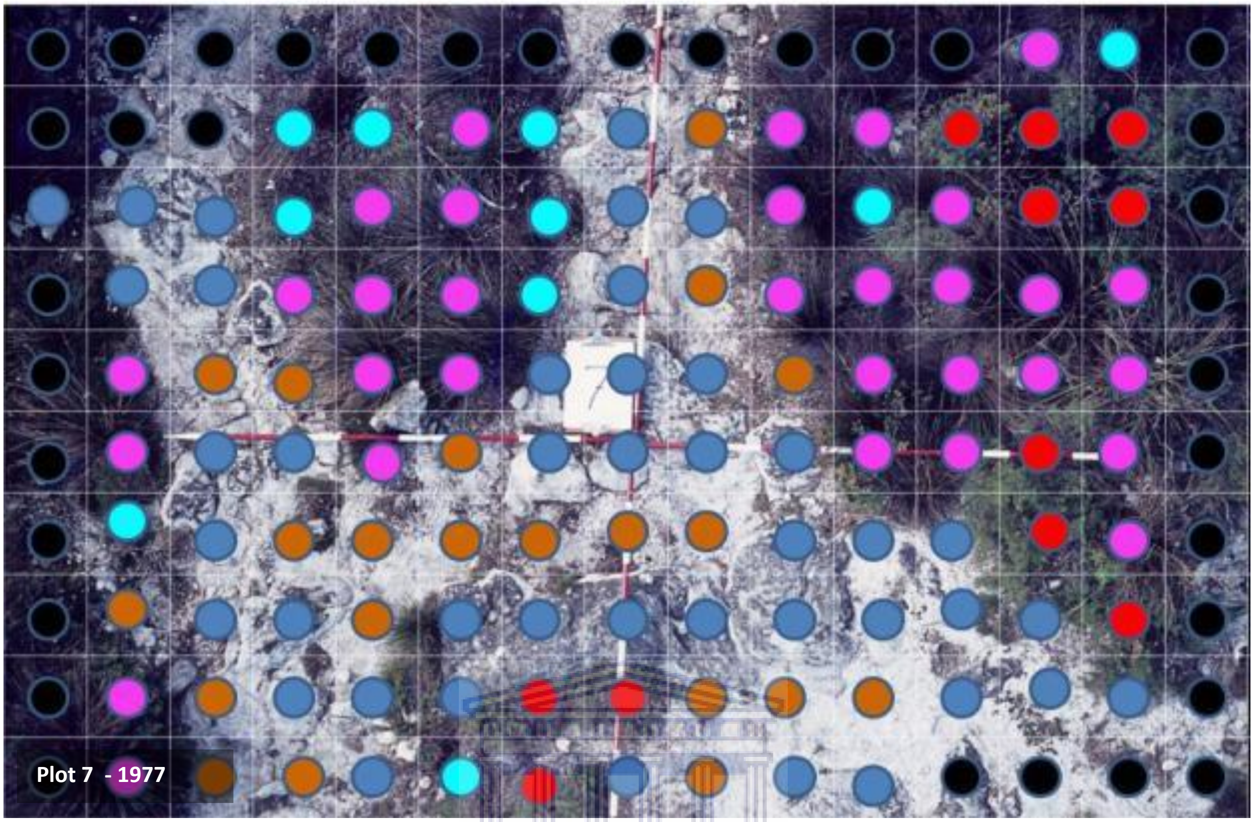
Plot 6

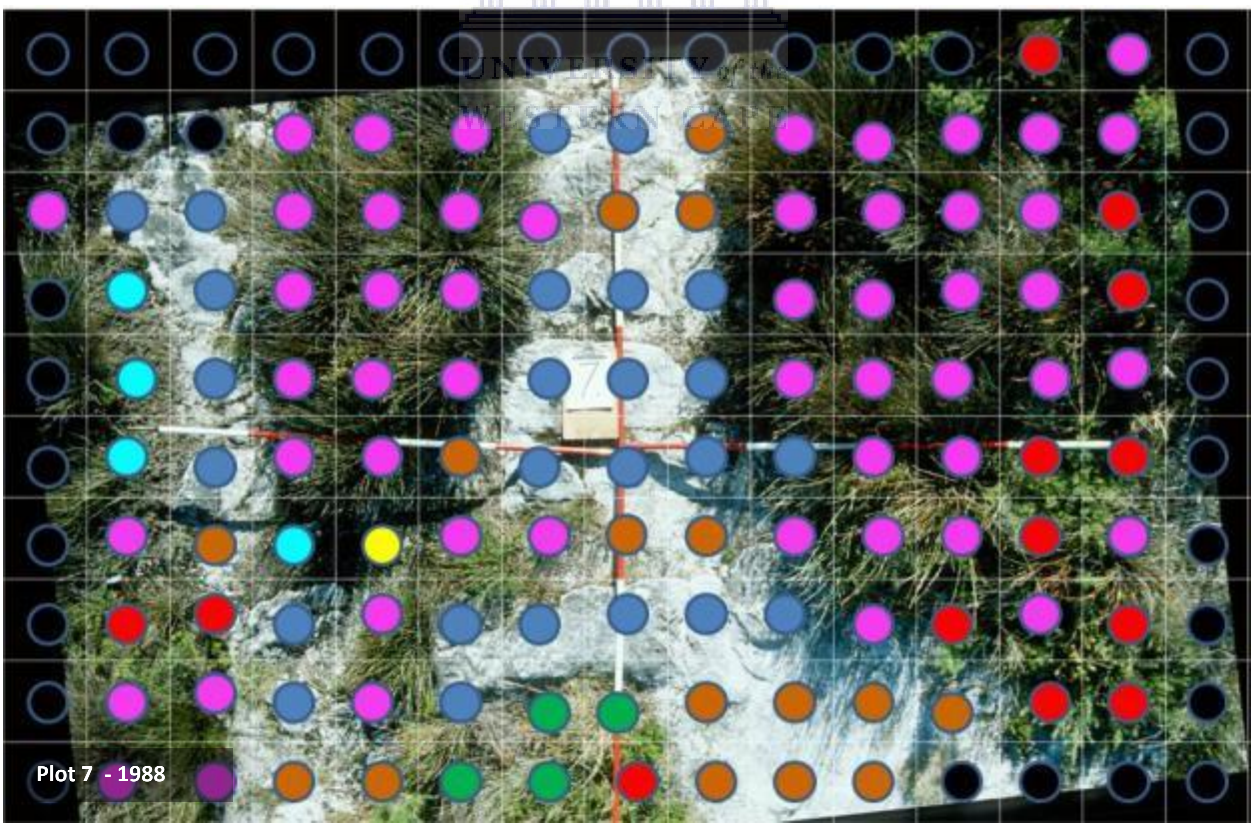
	2010									
	Rock	Sand	Restioid	Ericoid	Graminoid	Moss	Litter & dead material	Total 1988	Calculated %cover	Estimated %cover
Rock	13	0	5	10	2	2	12	44	40	40
Sand	3	2	4	4	0	0	4	17	15	15

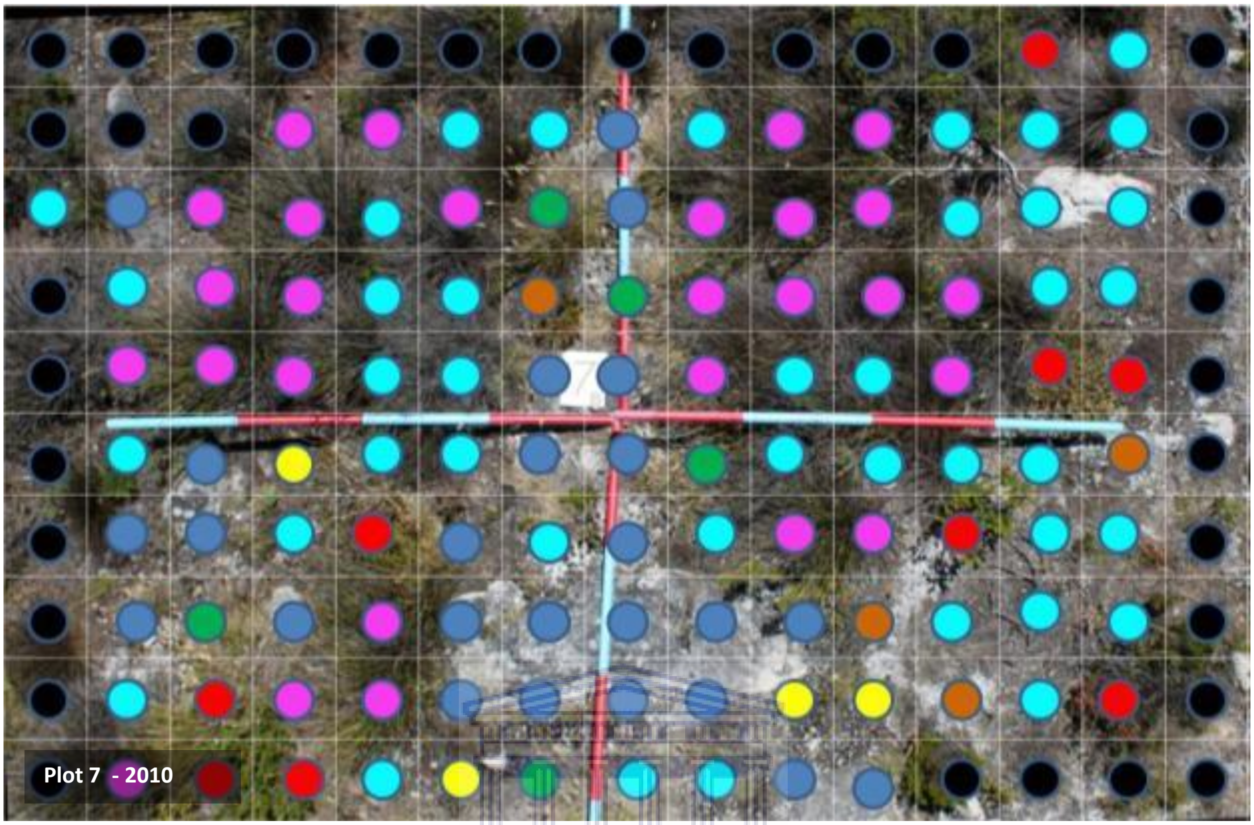
	Restioid	1	0	6	5	1	3	11	27	25	25
1988	Ericoid	1	0	1	2	0	1	3	8	7	7
	Graminoid	0	0	0	0	0	0	0	0	0	0
	Moss	1	0	3	2	0	1	5	12	11	11
	Litter & dead material	0	0	0	2	0	0	0	2	2	2
	Total 2010	19	2	19	25	3	7	35	**110**		
	Calculated %cover	17	2	17	23	3	6	32			
	Estimated %cover	22	1	17	13	2	20	25			

<u>Transition Matrix</u>

				2010					
		Rock	Sand	Restioid	Ericoid	Graminoid	Moss	Litter & dead material	
	Rock	0.295	0.000	0.114	0.227	0.045	0.045	0.273	1
	Sand	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0
	Restioid	0.037	0.000	0.222	0.185	0.037	0.111	0.407	1
1988	Ericoid & other	0.125	0.000	0.125	0.250	0.000	0.125	0.375	1
	Graminoid	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0
	Moss	0.125	0	0	0	0	0	0	0
	Litter & dead material	0.000	0	0	0	0	0	0	0


Plot 7 - 1977


Plot 7 - 1988



Cell Totals	Plot 7	1988										
		Rock	Sand	Restioid	Ericoid	Graminoid	Moss	Litter & dead material	Total 1977	Calculated %cover	Estimated %cover	
	Rock	21	7	8	5	0	0	1	42	37	45	Rock
	Sand	2	9	7	1	0	1	1	21	18	20	Sand
	Restioid	0	0	26	3	0	0	2	31	27	23	Restioid
1977	Ericoid	0	0	4	4	3	0	0	11	10	5	Ericoid
	Graminoid	0	0	0	0	0	0	0	0	0	0	Graminoid
	Moss	0	0	0	0	0	0	0	0	0	0	Moss
	Litter & dead material	2	0	7	0	1	0	0	10	9	7	Litter & dead material

	Rock	Sand	Restioid	Ericoid	Graminoid	Moss	Litter & dead material	
Total 1988	25	16	52	13	4	1	4	**115**
Calculated %cover	22	14	45	11	3	1	3	
Estimated %cover	35	10	37	8	1	6	3	

Transition Matrix

		1988							
		Rock	Sand	Restioid	Ericoid	Graminoid	Moss	Litter & dead material	
	Rock	0.500	0.167	0.190	0.119	0.000	0.000	0.024	1
	Sand	0.095	0.429	0.333	0.048	0.000	0.048	0.048	1
	Restioid	0.000	0.000	0.839	0.097	0.000	0.000	0.065	1
1977	Ericoid	0.000	0.000	0.364	0.364	0.273	0.000	0.000	1
	Graminoid	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
	Moss	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0
	Litter & dead material	0.200	0.000	0.700	0.000	0.100	0.000	0.000	1

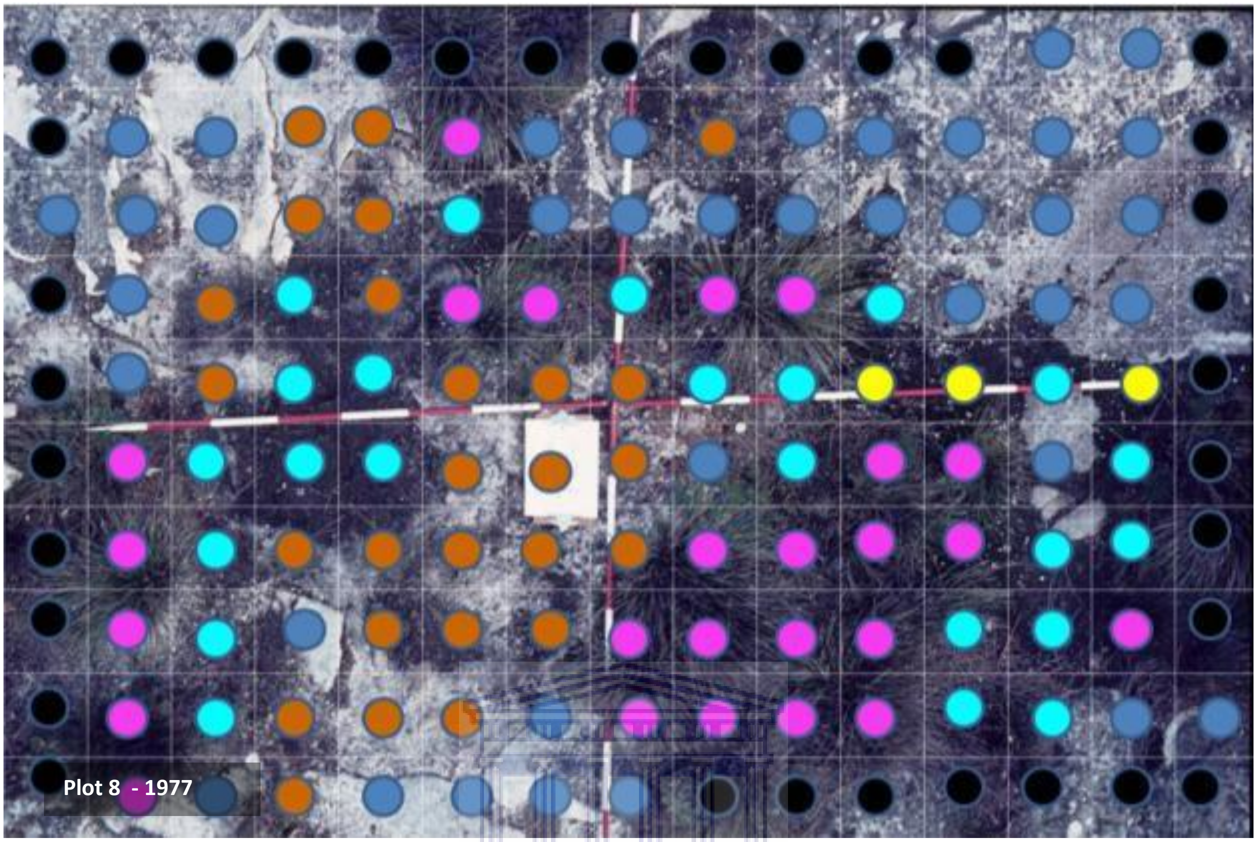
Cell Totals **Plot 7**

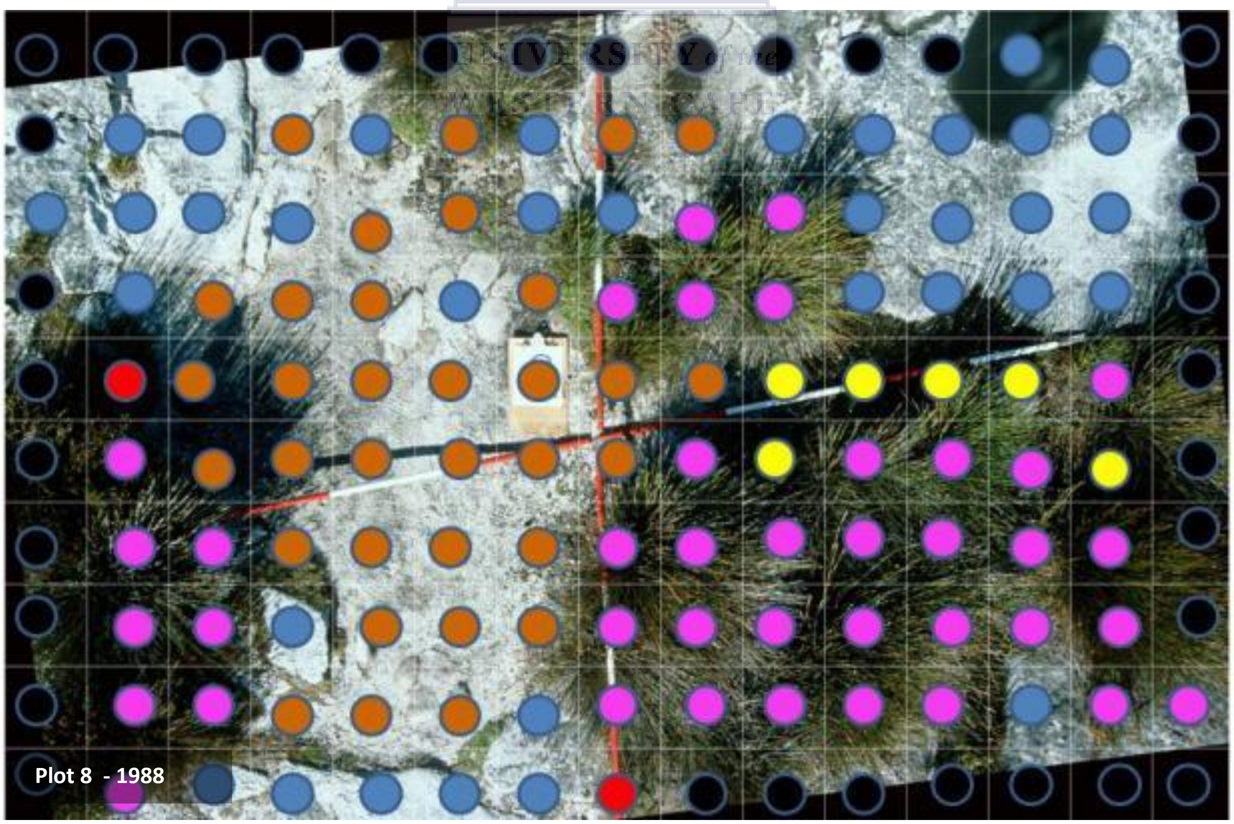
		2010									
		Rock	Sand	Restioid	Ericoid	Graminoid	Moss	Litter & dead material	Total 1988	Calculated %cover	Estimated %cover
	Rock	14	1	6	0	2	0	2	25	22	35
	Sand	6	1	1	1	0	2	5	16	14	10
	Restioid	2	1	19	5	1	1	23	52	45	37
1988	Ericoid	1	1	0	2	1	0	8	13	11	8
	Graminoid	2	0	0	0	1	1	0	4	3	1
	Moss	0	0	0	1	0	0	0	1	1	6
	Litter & dead material	0	0	1	0	0	0	3	4	3	3
	Total 2010	25	4	27	9	5	4	41	**115**		
	Calculated %cover	22	3	23	8	4	3	36			
	Estimated %cover	20	5	30	6	8	10	21			

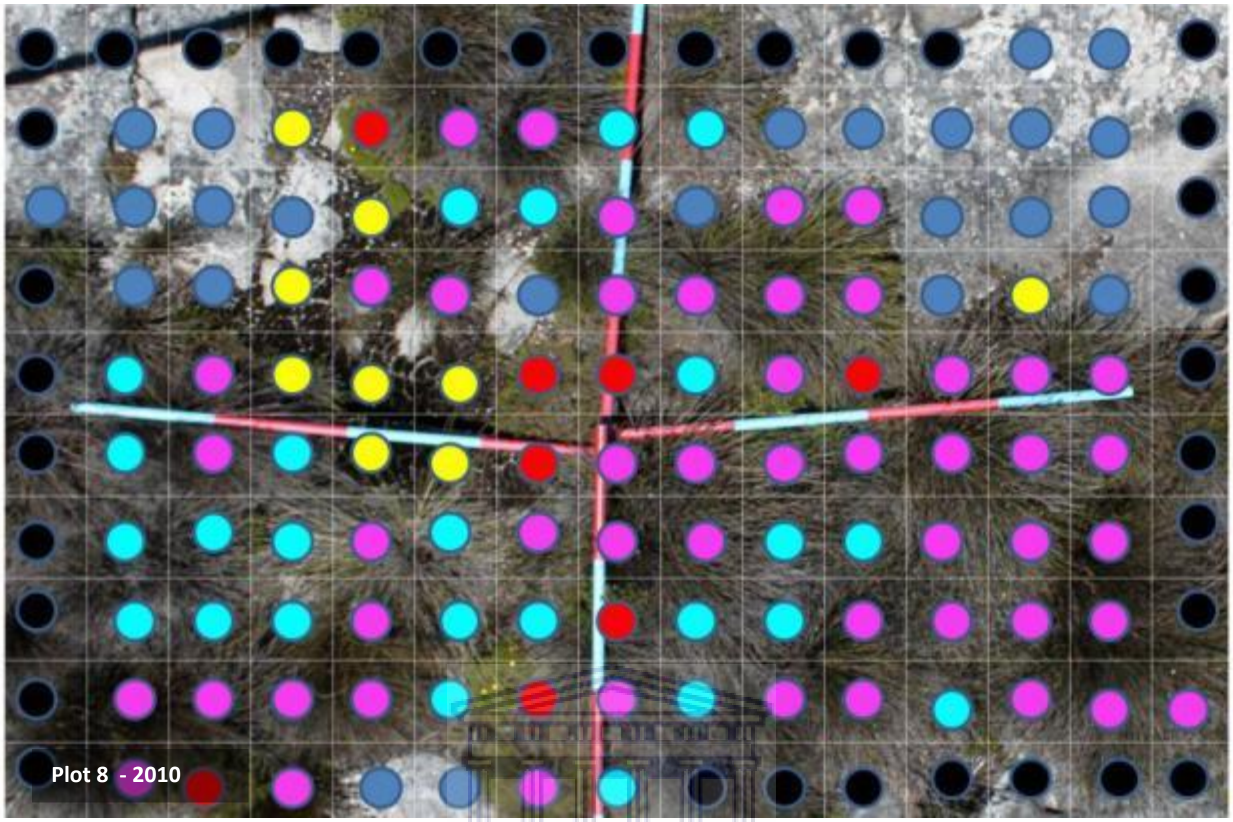
Transition Matrix

		2010						
		Rock	Sand	Restioid	Ericoid	Graminoid	Moss	Litter & dead material

	Rock	0.560	0.040	0.240	0.000	0.080	0.000	0.080	1
	Sand	0.375	0.063	0.063	0.063	0.000	0.125	0.313	1
	Restioid	0.038	0.019	0.365	0.096	0.019	0.019	0.442	1
1988	Ericoid & other	0.077	0.077	0.000	0.154	0.077	0.000	0.615	1
	Graminoid	0.154	0.000	0.000	0.000	0.000	0.000	0.000	0
	Moss	0.000	0	0	0	0	0	0	0
	Litter & dead material	0.000	0	0	0		0	0	0


Plot 8 - 1977


Plot 8 - 1988


Plot 8 - 2010

Cell Totals

Plot 8

		1988									
		Rock	Sand	Restioid	Ericoid	Graminoid	Moss	Litter & dead material	Total 1977	Calculated %cover	Estimated %cover
	Rock	29	1	6	2	0	0	0	38	33	25
	Sand	3	22	1	0	0	0	0	26	23	13
	Restioid	1	2	22	0	0	0	0	25	22	25
1977	Ericoid	0	0	0	0	0	0	0	0	0	2
	Graminoid	0	0	0	0	0	0	0	0	0	0
	Moss	0	0	1	0	0	2	0	3	3	0
	Litter & dead material	2	8	9	0	0	4	0	23	20	35
	Total 1988	35	33	39	2	0	6	0	**115**		
	Calculated %cover	30	29	34	2	0	5	0			
	Estimated %cover	21	35	40	1	0	0	3			

Transition Matrix

		1988							
		Rock	Sand	Restioid	Ericoid	Graminoid	Moss	Litter & dead material	
	Rock	0.763	0.026	0.158	0.053	0.000	0.000	0.000	1
	Sand	0.115	0.846	0.038	0.000	0.000	0.000	0.000	1
	Restioid	0.040	0.080	0.880	0.000	0.000	0.000	0.000	1
1977	Ericoid	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
	Graminoid	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
	Moss	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0
	Litter & dead material	0.087	0.348	0.391	0.000	0.000	0.174	0.000	1

Cell Totals

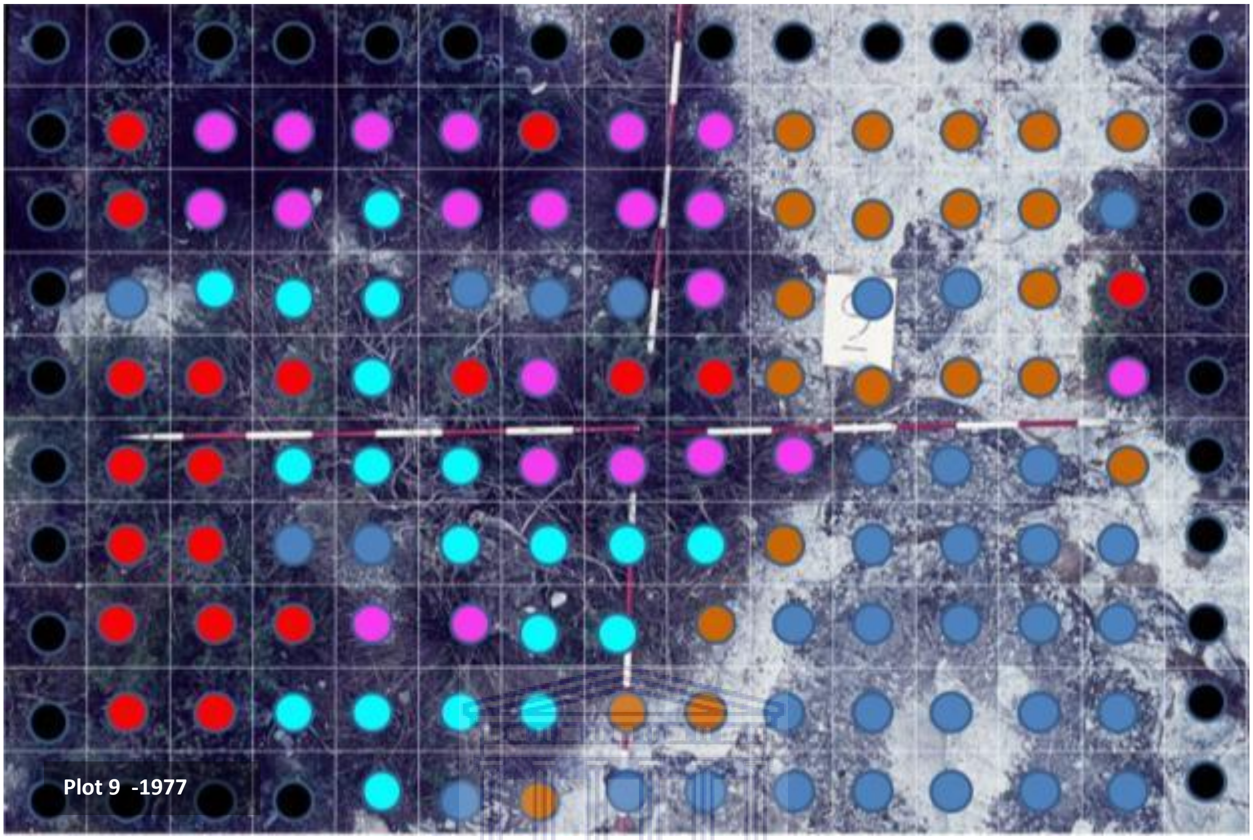
Plot 8

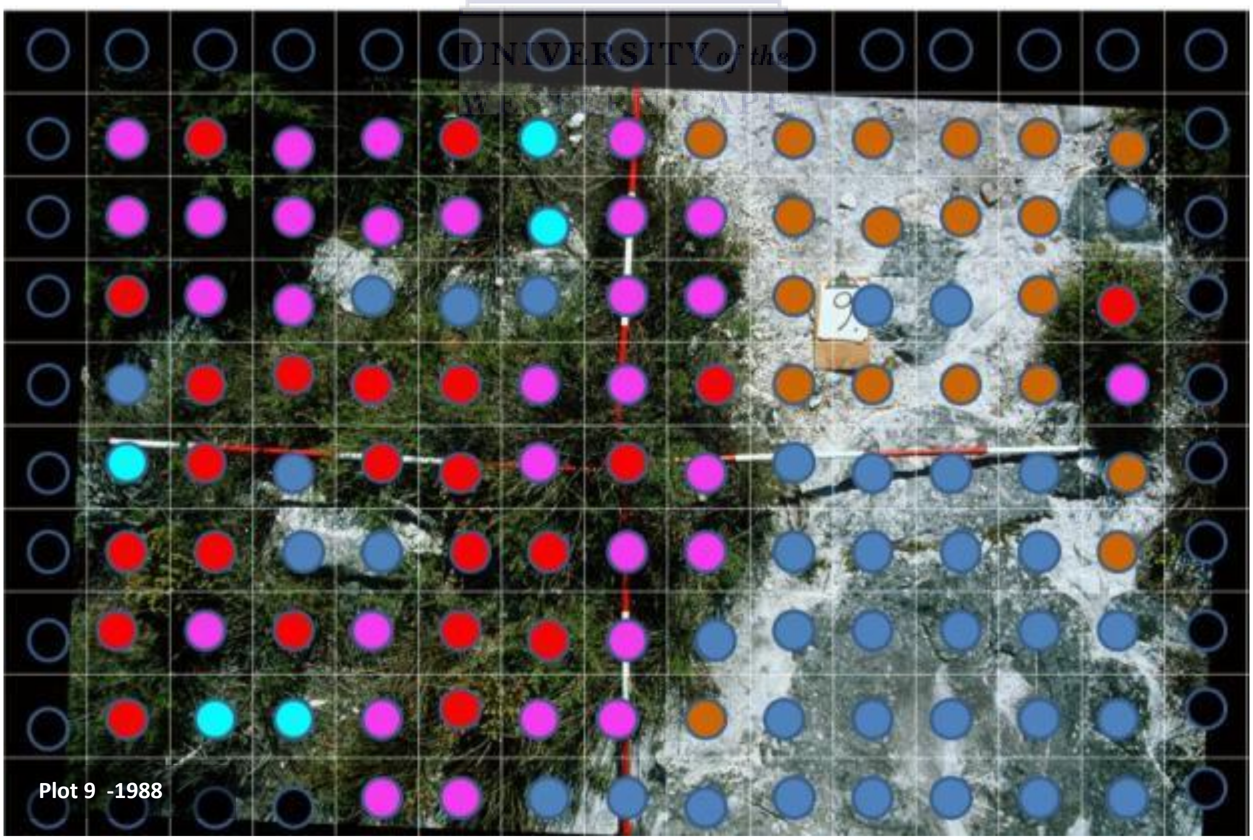
		2010									
		Rock	Sand	Restioid	Ericoid	Graminoid	Moss	Litter & dead material	Total 1988	Calculated %cover	Estimated %cover
	Rock	21	0	8	3	0	1	2	35	30	21
	Sand	2	0	10	3	0	8	10	33	29	35

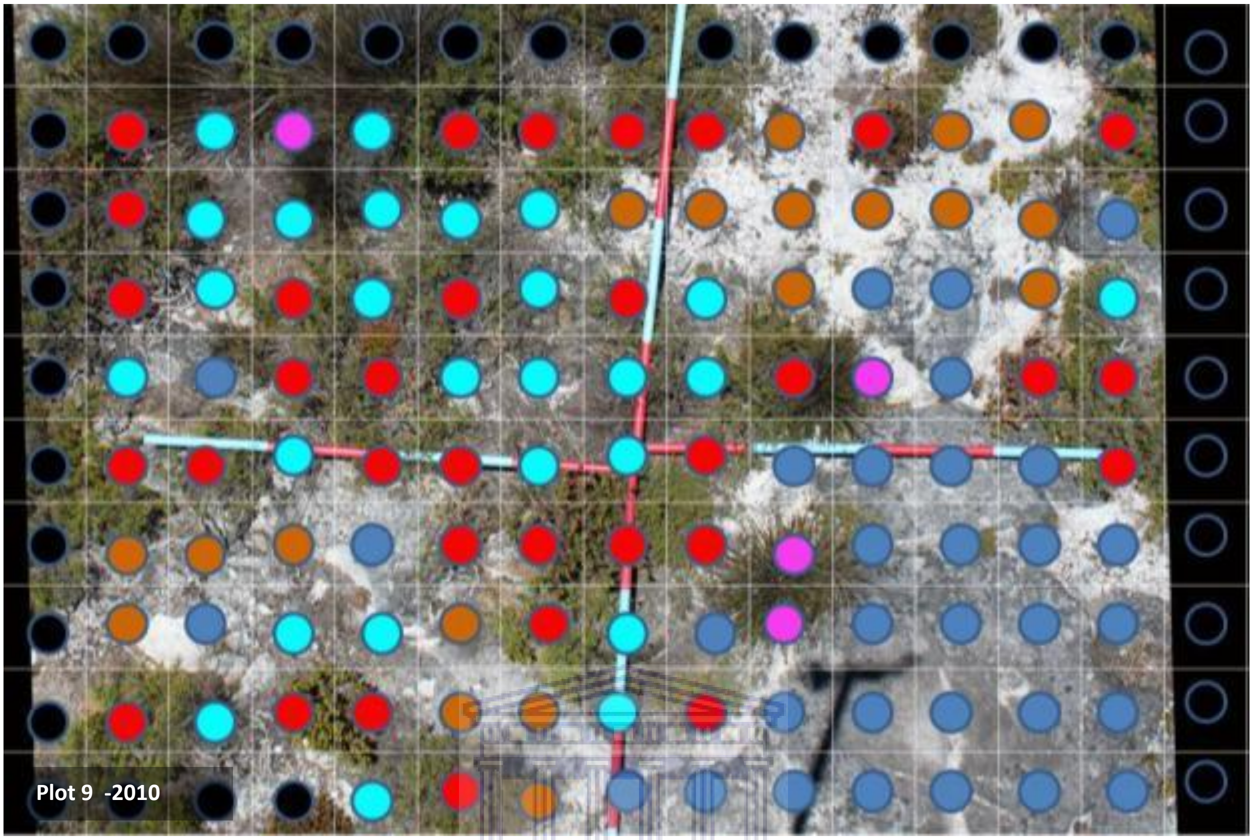
	Restioid	1	0	26	1	0	0	11	39	34	40
1988	Ericoid	0	0	0	0	0	0	2	2	2	1
	Graminoid	0	0	0	0	0	0	0	0	0	0
	Moss	0	0	5	1	0	0	0	6	5	0
	Litter & dead material	0	0	0	0	0	0	0	0	0	3
	Total 2010	24	0	49	8	0	9	25	**115**		
	Calculated %cover	21	0	43	7	0	8	22			
	Estimated %cover	24	0	39	3	0	4	30			

<u>Transition Matrix</u>

				2010					
		Rock	Sand	Restioid	Ericoid	Graminoid	Moss	Litter & dead material	
	Rock	0.600	0.000	0.229	0.086	0.000	0.029	0.057	1
	Sand	0.061	0.000	0.303	0.091	0.000	0.242	0.303	1
	Restioid	0.026	0.000	0.667	0.026	0.000	0.000	0.282	1
1988	Ericoid & other	0.000	0.000	0.000	0.000	0.000	0.000	1.000	1
	Graminoid	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0
	Moss	0.000	0	0	0	0	0	0	0
	Litter & dead material	0.000	0	0	0		0	0	0


Plot 9 -1977


Plot 9 -1988


Plot 9 -2010

Cell Totals

Plot 9

		1988									
		Rock	Sand	Restioid	Ericoid	Graminoid	Moss	Litter & dead material	Total 1977	Calculated %cover	Estimated %cover
	Rock	30	1	2	1	0	0	0	34	30	25
	Sand	3	17	1	0	0	0	0	21	18	20
	Restioid	1	1	14	4	0	0	1	21	18	10
1977	Ericoid	1	0	4	11	0	0	3	19	17	20
	Graminoid	0	0	0	0	0	0	0	0	0	0
	Moss	0	0	0	0	0	0	0	0	0	0
	Litter & dead material	2	0	9	7	0	0	1	19	17	25
	Total 1988	37	19	30	23	0	0	5	**114**		
	Calculated %cover	32	17	26	20	0	0	4			
	Estimated %cover	30	20	15	31	0	0	4			

Transition Matrix

		1988							
		Rock	Sand	Restioid	Ericoid	Graminoid	Moss	Litter & dead material	
	Rock	0.882	0.029	0.059	0.029	0.000	0.000	0.000	1
	Sand	0.143	0.810	0.048	0.000	0.000	0.000	0.000	1
	Restioid	0.048	0.048	0.667	0.190	0.000	0.000	0.048	1
1977	Ericoid	0.053	0.000	0.211	0.579	0.000	0.000	0.158	1
	Graminoid	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
	Moss	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0
	Litter & dead material	0.105	0.000	0.474	0.368	0.000	0.000	0.053	1

Cell Totals

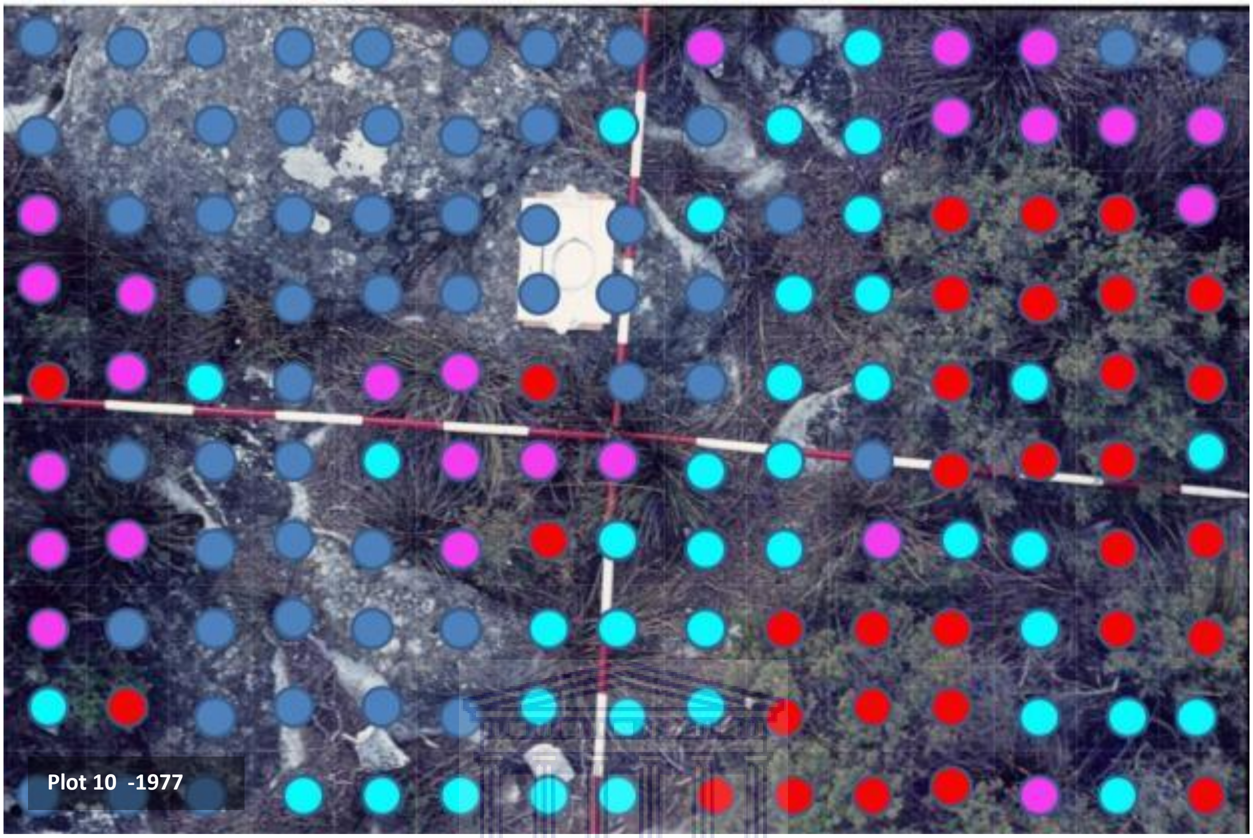
Plot 9

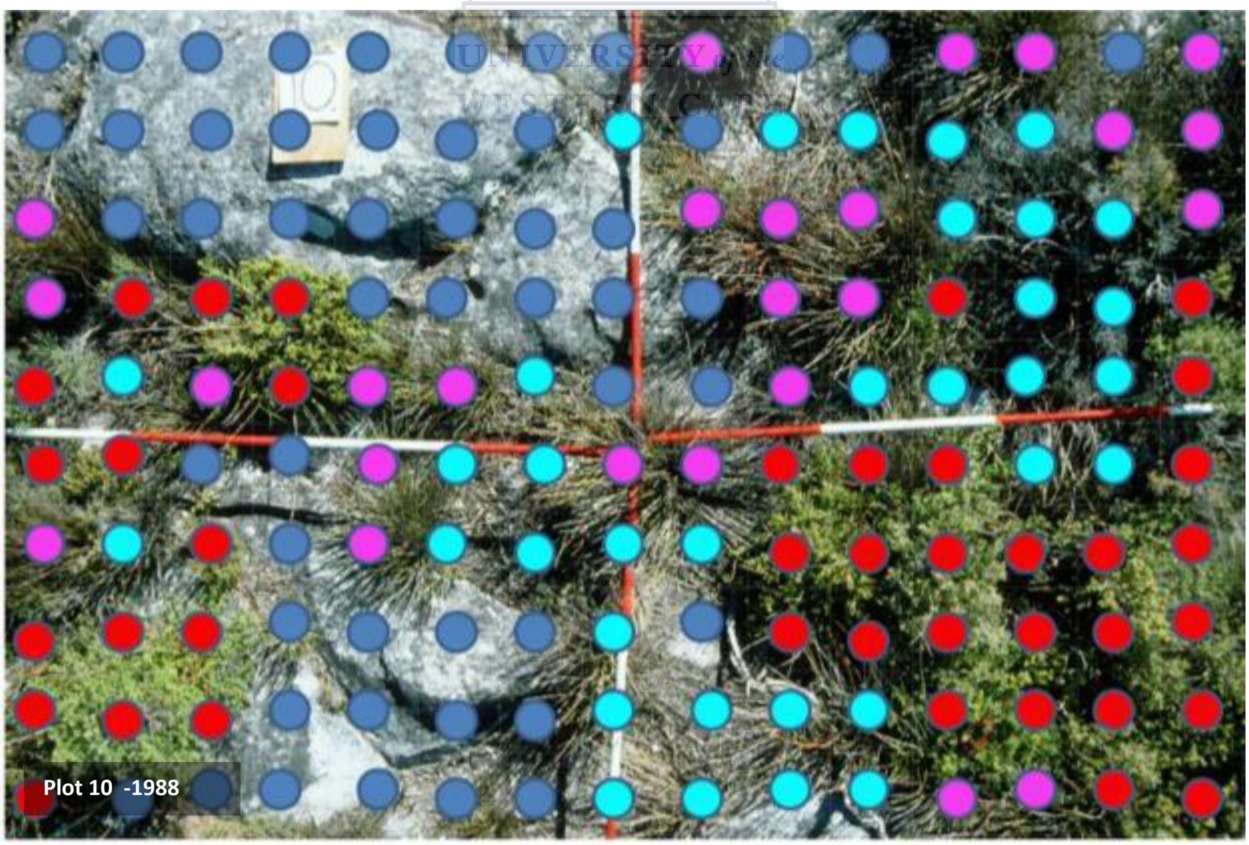
		2010									
		Rock	Sand	Restioid	Ericoid	Graminoid	Moss	Litter & dead material	Total 1988	Calculated %cover	Estimated %cover
	Rock	28	2	2	1	0	0	4	37	33	30
	Sand	2	9	1	6	0	0	0	18	16	20

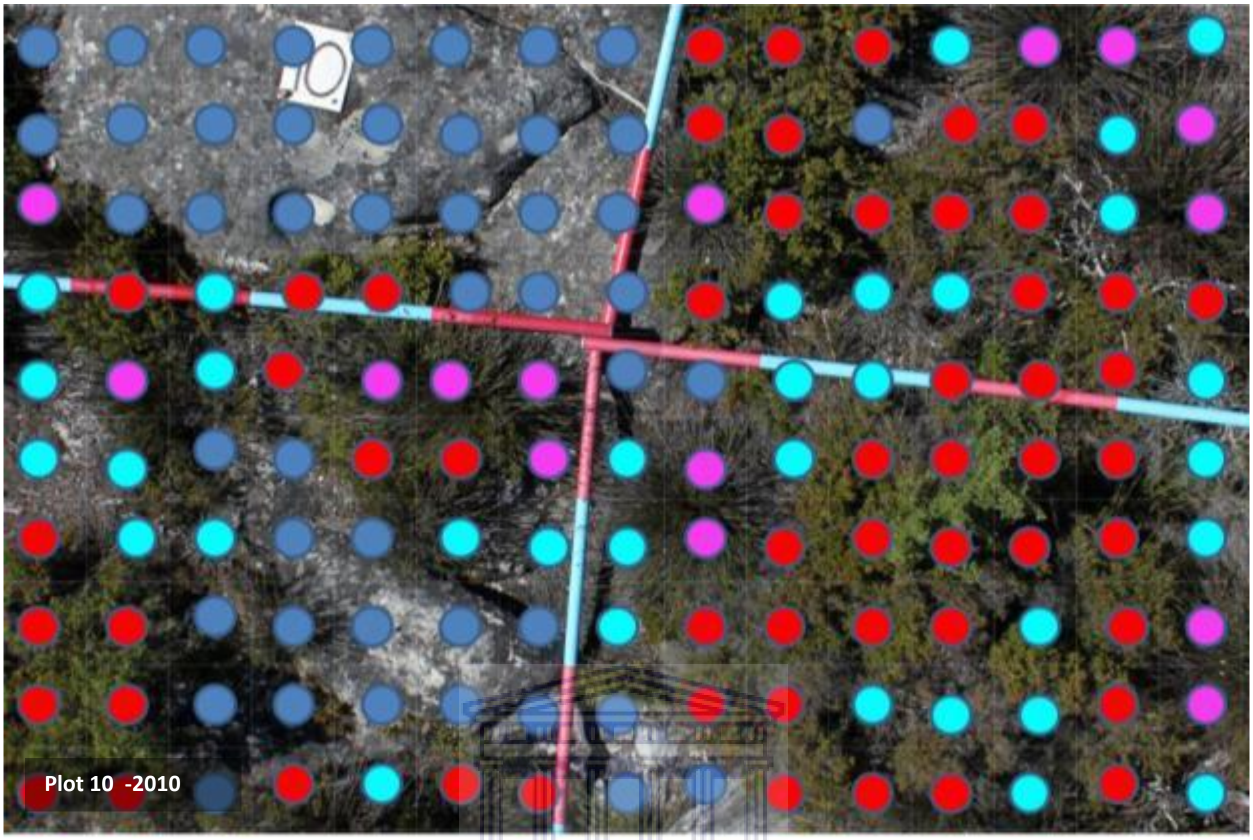
	Restioid	1	3	1	11	0	0	14	30	27	15
1988	Ericoid	1	5	0	11	0	0	6	23	20	31
	Graminoid	0	0	0	0	0	0	0	0	0	0
	Moss	0	0	0	0	0	0	0	0	0	0
	Litter & dead material	0	0	0	3	0	0	2	5	4	4
	Total 2010	32	19	4	32	0	0	26	**113**		
	Calculated %cover	28	17	4	28	0	0	23			
	Estimated %cover	35	15	4	20	1	0	25			

Transition Matrix

				2010					
		Rock	Sand	Restioid	Ericoid	Graminoid	Moss	Litter & dead material	
	Rock	0.757	0.054	0.054	0.027	0.000	0.000	0.108	1
	Sand	0.111	0.500	0.056	0.333	0.000	0.000	0.000	1
	Restioid	0.033	0.100	0.033	0.367	0.000	0.000	0.467	1
1988	Ericoid & other	0.043	0.217	0.000	0.478	0.000	0.000	0.261	1
	Graminoid	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0
	Moss	0.000	0	0	0	0	0	0	0
	Litter & dead material	0.000	0	0	0		0	0	0


Plot 10 -1977


Plot 10 -1988


Plot 10 -2010

Cell Totals

Plot 10

		1988									
		Rock	Sand	Restioid	Ericoid	Graminoid	Moss	Litter & dead material	Total 1977	Calculated %cover	Estimated %cover
	Rock	43	0	3	10	0	0	0	56	37	45
	Sand	0	0	0	0	0	0	0	0	0	0
	Restioid	0	0	13	4	0	0	7	24	16	20
1977	Ericoid	0	0	1	15	0	0	16	32	21	20
	Graminoid	0	0	0	0	0	0	0	0	0	0
	Moss	0	0	0	0	0	0	0	0	0	0
	Litter & dead material	8	0	8	11	0	0	11	38	25	15
	Total 1988	51	0	25	40	0	0	34	**150**		
	Calculated %cover	34	0	17	27	0	0	23			
	Estimated %cover	40	1	14	25	0	0	20			

Transition Matrix

		1988							
		Rock	Sand	Restioid	Ericoid	Graminoid	Moss	Litter & dead material	
	Rock	0.768	0.000	0.054	0.179	0.000	0.000	0.000	1
	Sand	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
	Restioid	0.000	0.000	0.542	0.167	0.000	0.000	0.292	1
1977	Ericoid	0.000	0.000	0.031	0.469	0.000	0.000	0.500	1
	Graminoid	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
	Moss	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0
	Litter & dead material	0.211	0.000	0.211	0.289	0.000	0.000	0.289	1

Cell Totals

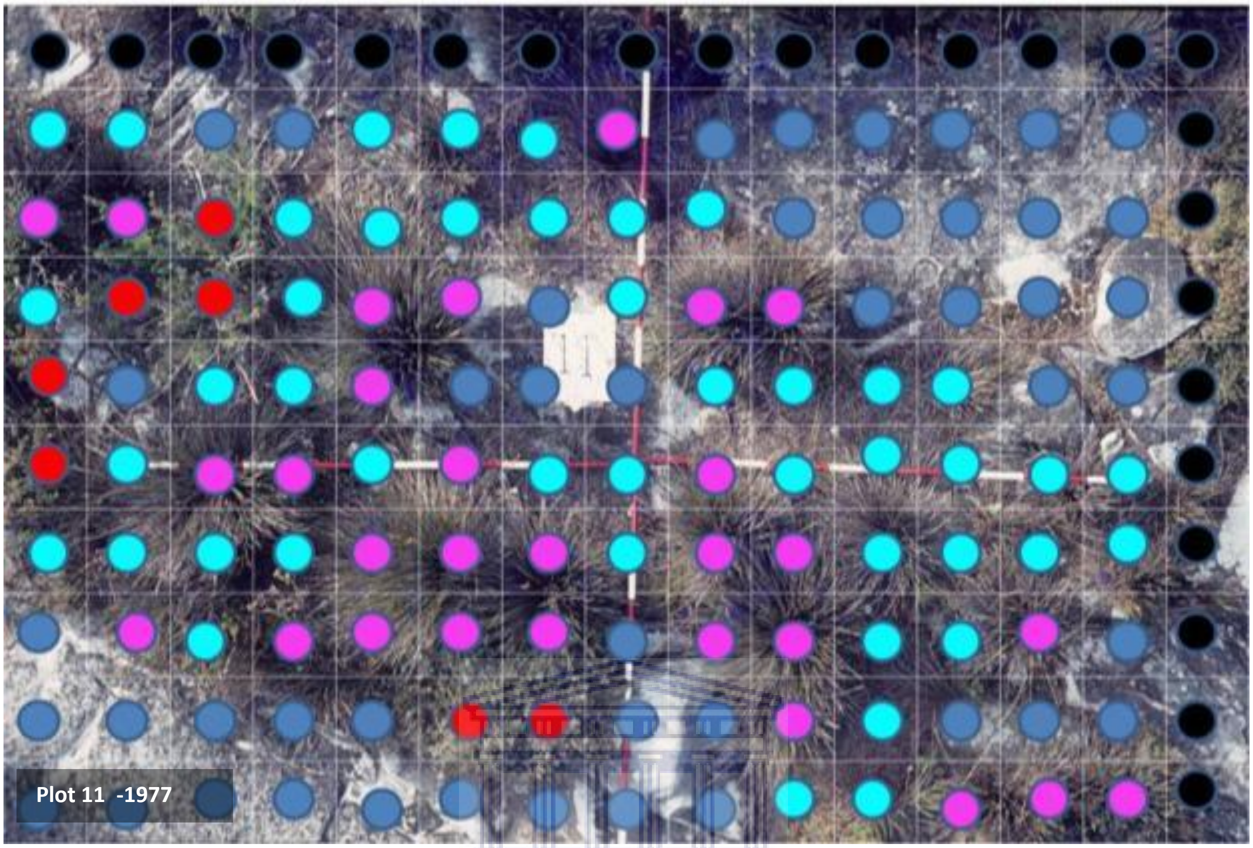
Plot 10

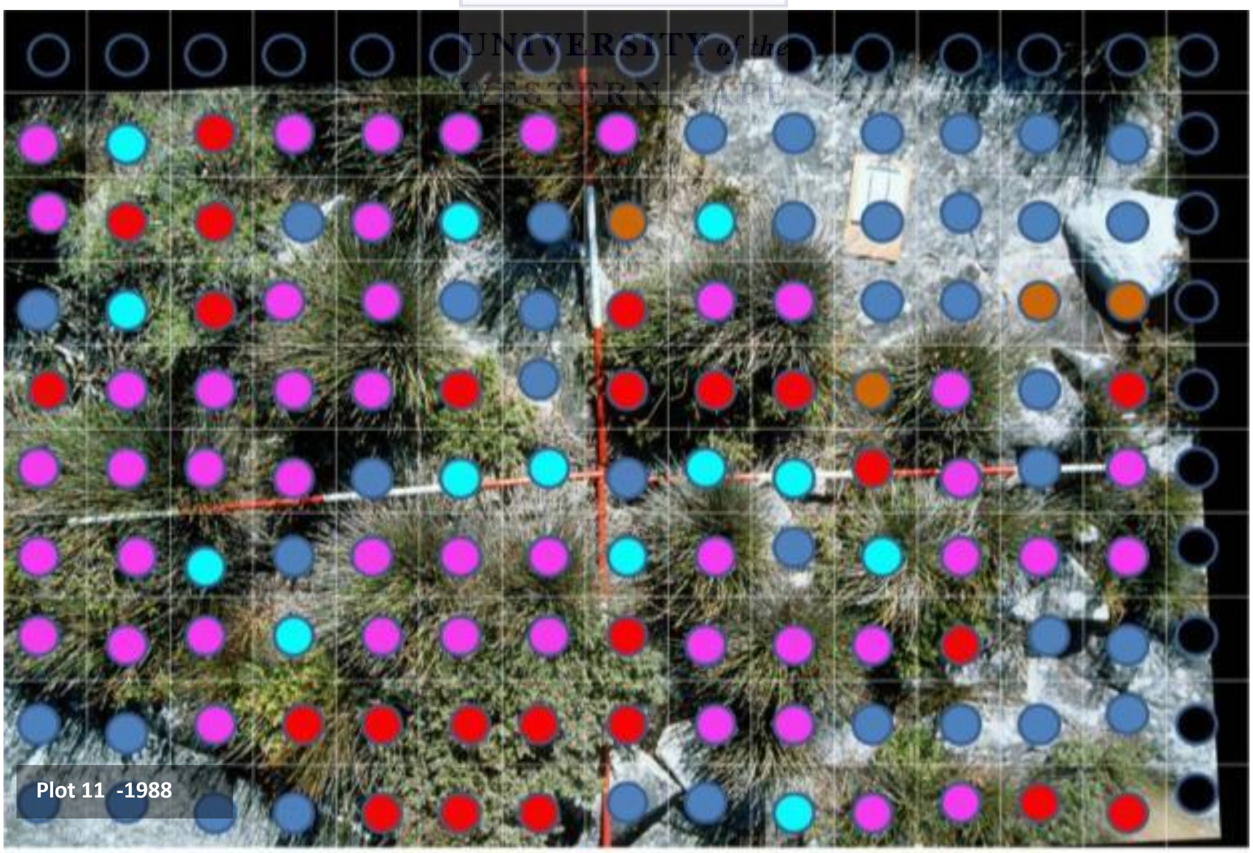
	2010									
	Rock	Sand	Restioid	Ericoid	Graminoid	Moss	Litter & dead material	Total 1988	Calculated %cover	Estimated %cover
Rock	38	0	1	10	0	0	1	50	33	40
Sand	0	0	0	0	0	0	0	0	0	1

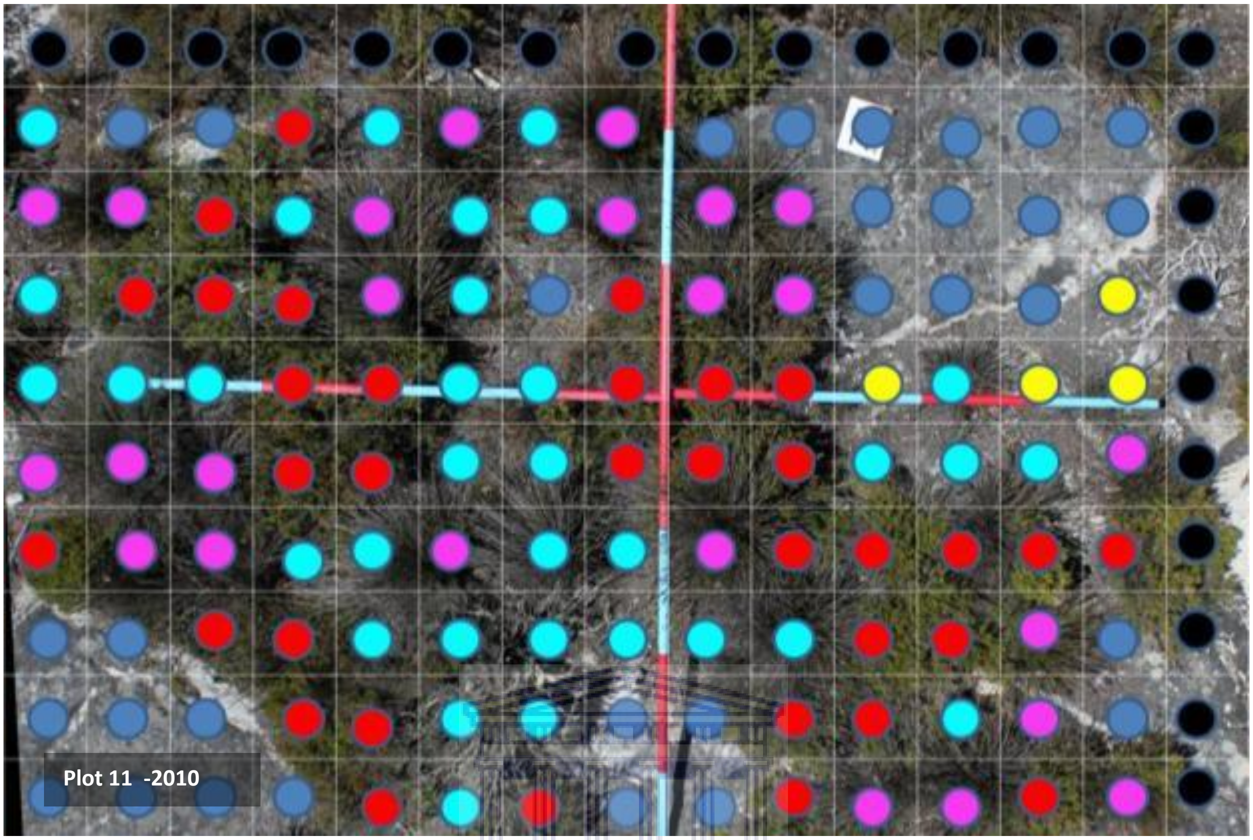
	Restioid	1	0	8	6	0	0	11	26	17	14
1988	Ericoid	3	0	2	22	0	0	14	41	27	25
	Graminoid	0	0	0	0	0	0	0	0	0	0
	Moss	0	0	0	0	0	0	0	0	0	0
	Litter & dead material	5	0	4	17	0	0	7	33	22	20
	Total 2010	47	0	15	55	0	0	33	**150**		
	Calculated %cover	31	0	10	37	0	0	22		55	
	Estimated %cover	37	0	16	35	0	0	12			

<u>Transition Matrix</u>

		2010							
		Rock	Sand	Restioid	Ericoid	Graminoid	Moss	Litter & dead material	
	Rock	0.760	0.000	0.020	0.200	0.000	0.000	0.020	1
	Sand	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
	Restioid	0.038	0.000	0.308	0.231	0.000	0.000	0.423	1
1988	Ericoid & other	0.073	0.000	0.049	0.537	0.000	0.000	0.341	1
	Graminoid	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0
	Moss	0.000	0	0	0	0	0	0	0
	Litter & dead material	0.000	0	0	0		0	0	0


Plot 11 -1977


Plot 11 -1988


Plot 11 -2010

Cell Totals

Plot 11

		1988									
		Rock	Sand	Restioid	Ericoid	Graminoid	Moss	Litter & dead material	Total 1977	Calculated %cover	Estimated %cover
	Rock	28	2	5	11	0	0	0	46	37	40
	Sand	0	0	0	0	0	0	0	0	0	0
	Restioid	3	0	20	3	0	0	3	29	23	30
1977	Ericoid	0	0	1	5	0	0	1	7	6	8
	Graminoid	0	0	0	0	0	0	0	0	0	0
	Moss	0	0	0	0	0	0	0	0	0	0
	Litter & dead material	8	2	20	5	0	0	9	44	35	22
	Total 1988	39	4	46	24	0	0	13	**126**		
	Calculated %cover	31	3	37	19	0	0	10		24	
	Estimated %cover	37	0	40	14	0	0	9			

Transition Matrix

		1988							
		Rock	Sand	Restioid	Ericoid	Graminoid	Moss	Litter & dead material	
	Rock	0.609	0.043	0.109	0.239	0.000	0.000	0.000	1
	Sand	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
	Restioid	0.103	0.000	0.690	0.103	0.000	0.000	0.103	1
1977	Ericoid	0.000	0.000	0.143	0.714	0.000	0.000	0.143	1
	Graminoid	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
	Moss	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0
	Litter & dead material	0.182	0.045	0.455	0.114	0.000	0.000	0.205	1

Cell Totals

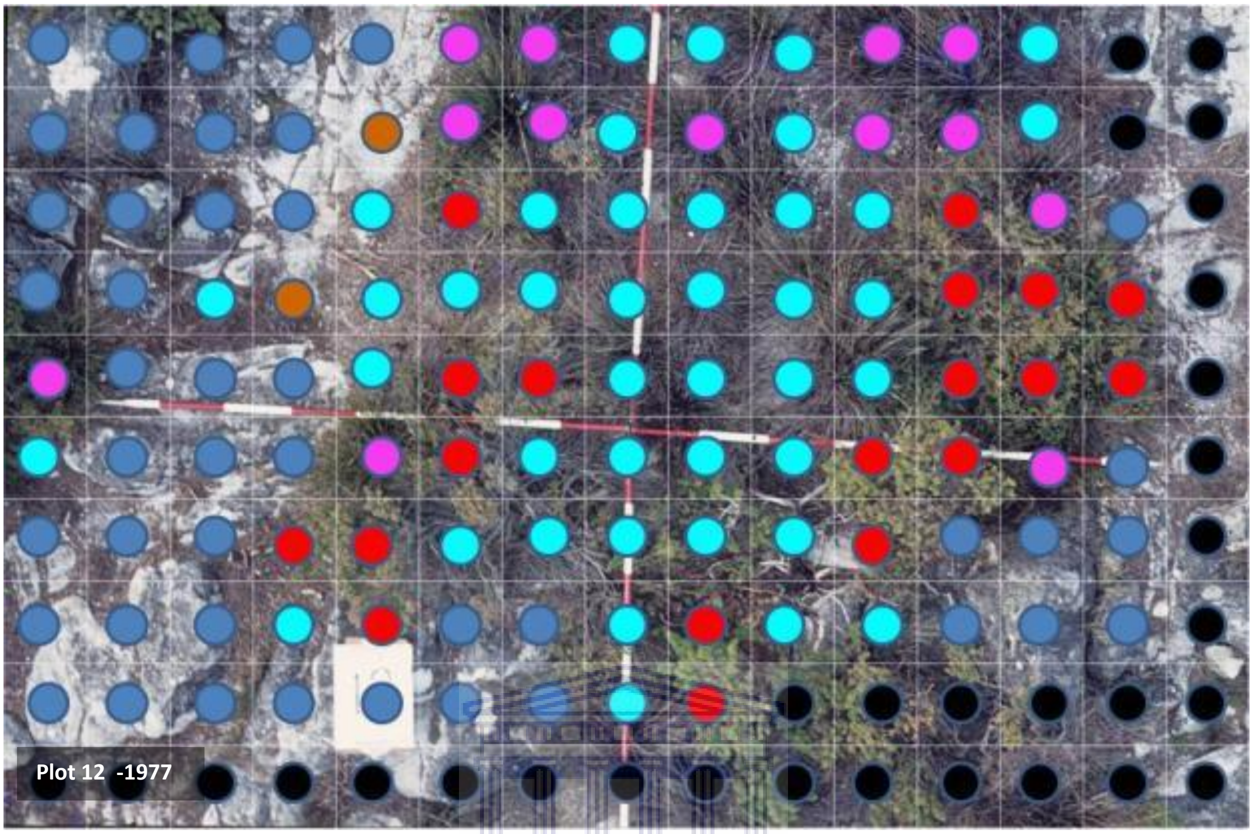
Plot 11

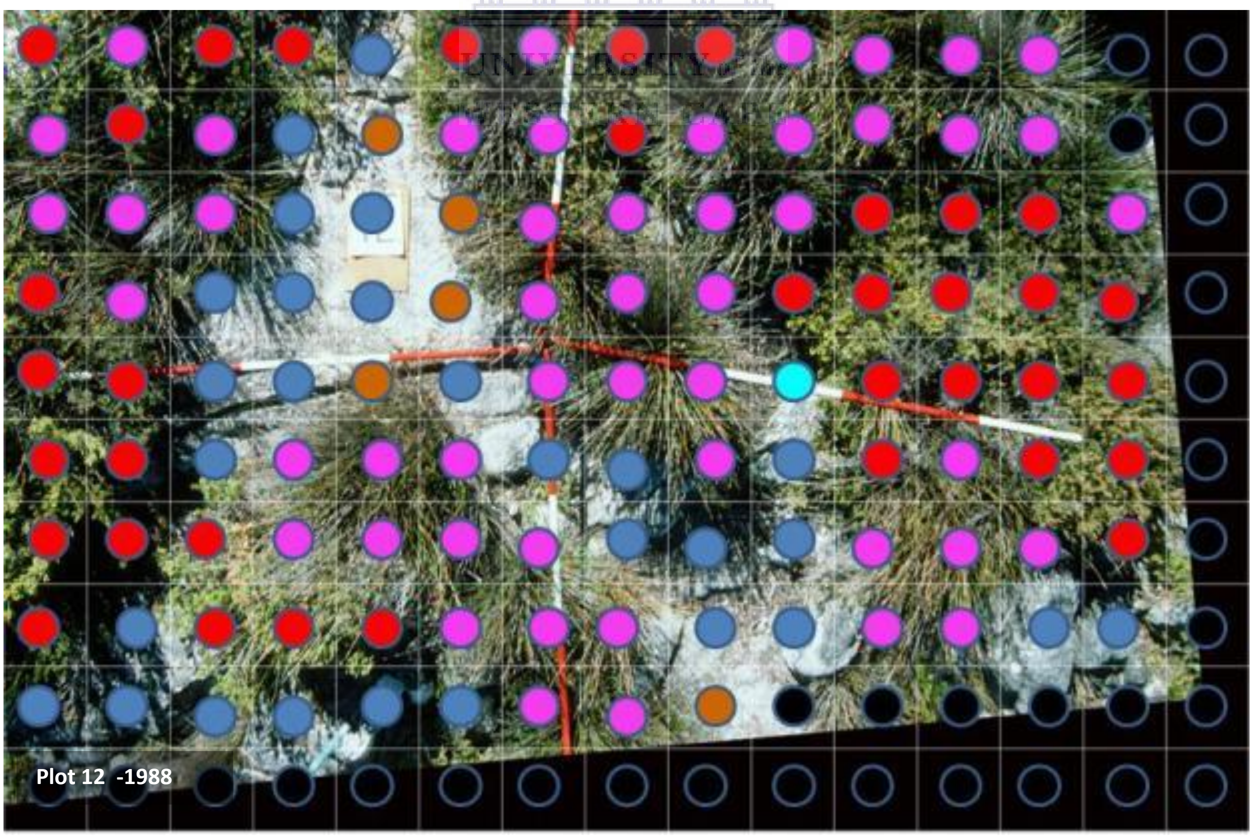
	2010									
	Rock	Sand	Restioid	Ericoid	Graminoid	Moss	Litter & dead material	Total 1988	Calculated %cover	Estimated %cover
Rock	23	0	3	4	0	1	8	39	31	37
Sand	1	0	1	0	0	2	0	4	3	0

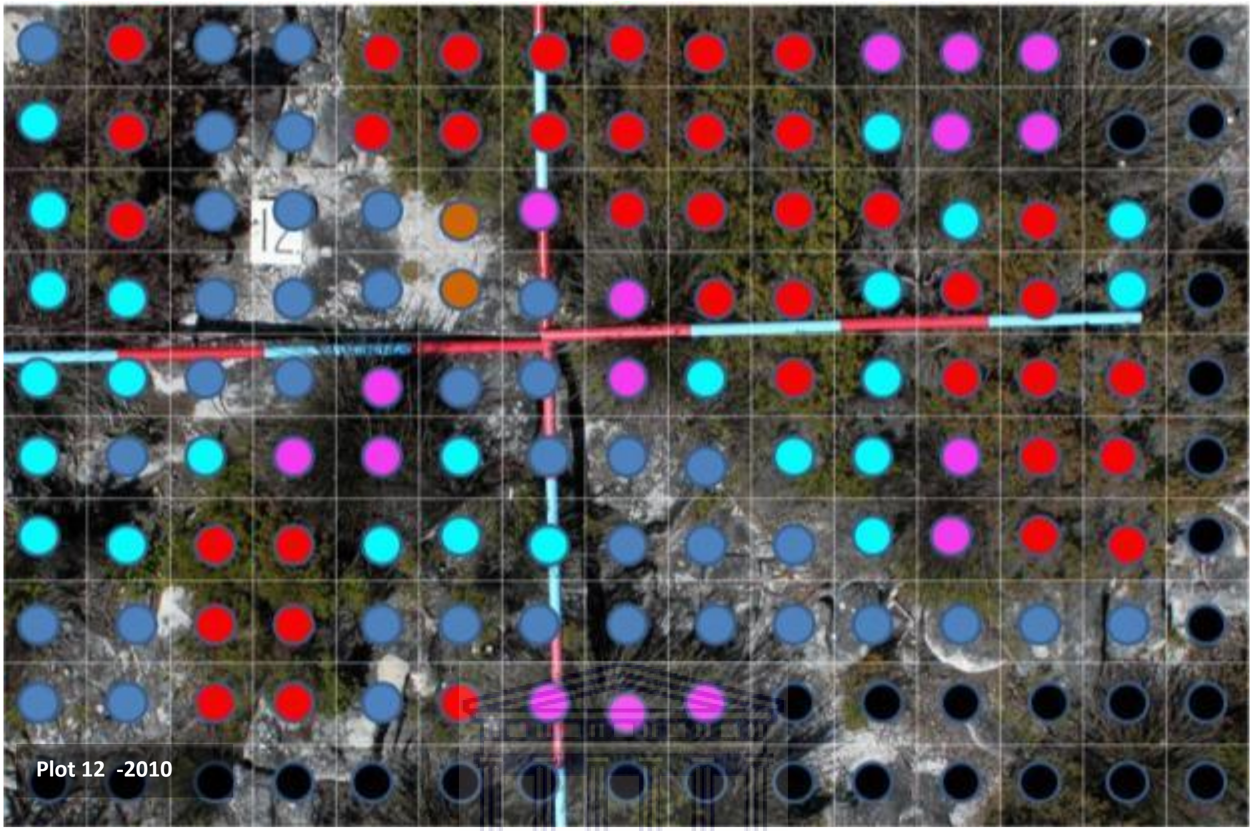
	Restioid	4	0	16	12	0	0	14	46	37	40
1988	Ericoid	2	0	2	12	0	1	7	24	19	14
	Graminoid	0	0	0	0	0	0	0	0	0	0
	Moss	0	0	0	0	0	0	0	0	0	0
	Litter & dead material	1	0	2	6	0	0	4	13	10	9
	Total 2010	31	0	24	34	0	4	33	**126**		
	Calculated %cover	25	0	19	27	0	3	26			
	Estimated %cover	25	5	25	26	0	4	15			

<u>Transition Matrix</u>

		2010							
		Rock	Sand	Restioid	Ericoid	Graminoid	Moss	Litter & dead material	
	Rock	0.590	0.000	0.077	0.103	0.000	0.026	0.205	1
	Sand	0.250	0.000	0.250	0.000	0.000	0.500	0.000	1
	Restioid	0.087	0.000	0.348	0.261	0.000	0.000	0.304	1
1988	Ericoid & other	0.083	0.000	0.083	0.500	0.000	0.042	0.292	1
	Graminoid	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0
	Moss	0.000	0	0	0	0	0	0	0
	Litter & dead material	0.000	0	0	0		0	0	0


Plot 12 -1977


Plot 12 -1988


Plot 12 -2010

Cell Totals

Plot 12

		1988									
		Rock	Sand	Restioid	Ericoid	Graminoid	Moss	Litter & dead material	Total 1977	Calculated %cover	Estimated %cover
	Rock	15	0	15	14	0	0	0	44	37	30
	Sand	1	1	0	0	0	0	0	2	2	2
	Restioid	0	0	9	4	0	0	0	13	11	15
1977	Ericoid	2	2	6	9	0	0	0	19	16	18
	Graminoid	0	0	0	0	0	0	0	0	0	0
	Moss	0	0	0	0	0	0	0	0	0	0
	Litter & dead material	10	2	19	9	0	0	1	41	34	35
	Total 1988	28	5	49	36	0	0	1	**119**		
	Calculated %cover	24	4	41	30	0	0	1			
	Estimated %cover	23	8	35	30	0	0	4			

Transition Matrix

				1988					
		Rock	Sand	Restioid	Ericoid	Graminoid	Moss	Litter & dead material	
	Rock	0.341	0.000	0.341	0.318	0.000	0.000	0.000	1
	Sand	0.500	0.500	0.000	0.000	0.000	0.000	0.000	1
	Restioid	0.000	0.000	0.692	0.308	0.000	0.000	0.000	1
1977	Ericoid	0.105	0.105	0.316	0.474	0.000	0.000	0.000	1
	Graminoid	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
	Moss	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0
	Litter & dead material	0.244	0.049	0.463	0.220	0.000	0.000	0.024	1

Cell Totals

Plot 12

		2010									
		Rock	Sand	Restioid	Ericoid	Graminoid	Moss	Litter & dead material	Total 1988	Calculated %cover	Estimated %cover
	Rock	22	0	0	4	0	0	2	28	24	23
	Sand	0	2	2	1	0	0	0	5	4	8

	Restioid	10	0	14	14	0	0	11	49	41	35
1988	Ericoid	6	0	0	19	0	0	11	36	30	30
	Graminoid	0	0	0	0	0	0	0	0	0	0
	Moss	0	0	0	0	0	0	0	0	0	0
	Litter & dead material	0	0	0	1	0	0	0	1	1	4
	Total 2010	38	2	16	39	0	0	24	**119**		
	Calculated %cover	32	2	13	33	0	0	20			
	Estimated %cover	34	4	24	30	0	0	8			

Transition Matrix

				2010					
		Rock	Sand	Restioid	Ericoid	Graminoid	Moss	Litter & dead material	
	Rock	0.786	0.000	0.000	0.143	0.000	0.000	0.071	1
	Sand	0.000	0.400	0.400	0.200	0.000	0.000	0.000	1
	Restioid	0.204	0.000	0.286	0.286	0.000	0.000	0.224	1
1988	Ericoid & other	0.167	0.000	0.000	0.528	0.000	0.000	0.306	1
	Graminoid	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0
	Moss	0.000	0	0	0	0	0	0	0
	Litter & dead material	0.000	0	0	0		0	0	0

Appendix E: Plot position coordinates

Plot	Latitude	Longitude
1	33°57'28.97"S	18°24'14.41"E
***2**	33°57'28.75"S	18°24'14.72"E
***3**	33°57'29.82"S	18°24'15.03"E
4e	33°57'29.42"S	18°24'15.28"E
5e	33°57'29.69"S	18°24'15.71"E
6e	33°57'29.83"S	18°24'16.54"E
7	33°57'30.31"S	18°24'16.06"E
8	33°57'30.83"S	18°24'15.69"E
9	33°57'30.56"S	18°24'16.52"E
10	33°57'34.31"S	18°24'20.21"E
11	33°57'33.79"S	18°24'20.32"E
12	33°57'33.65"S	18°24'20.77"E

*= approximate position since plots markers were either paved over or removed

Appendix F: The proportion of cases estimated that were off by more than 10% when compared with counted cover values in the transition matrix (data presented in Appendix D)

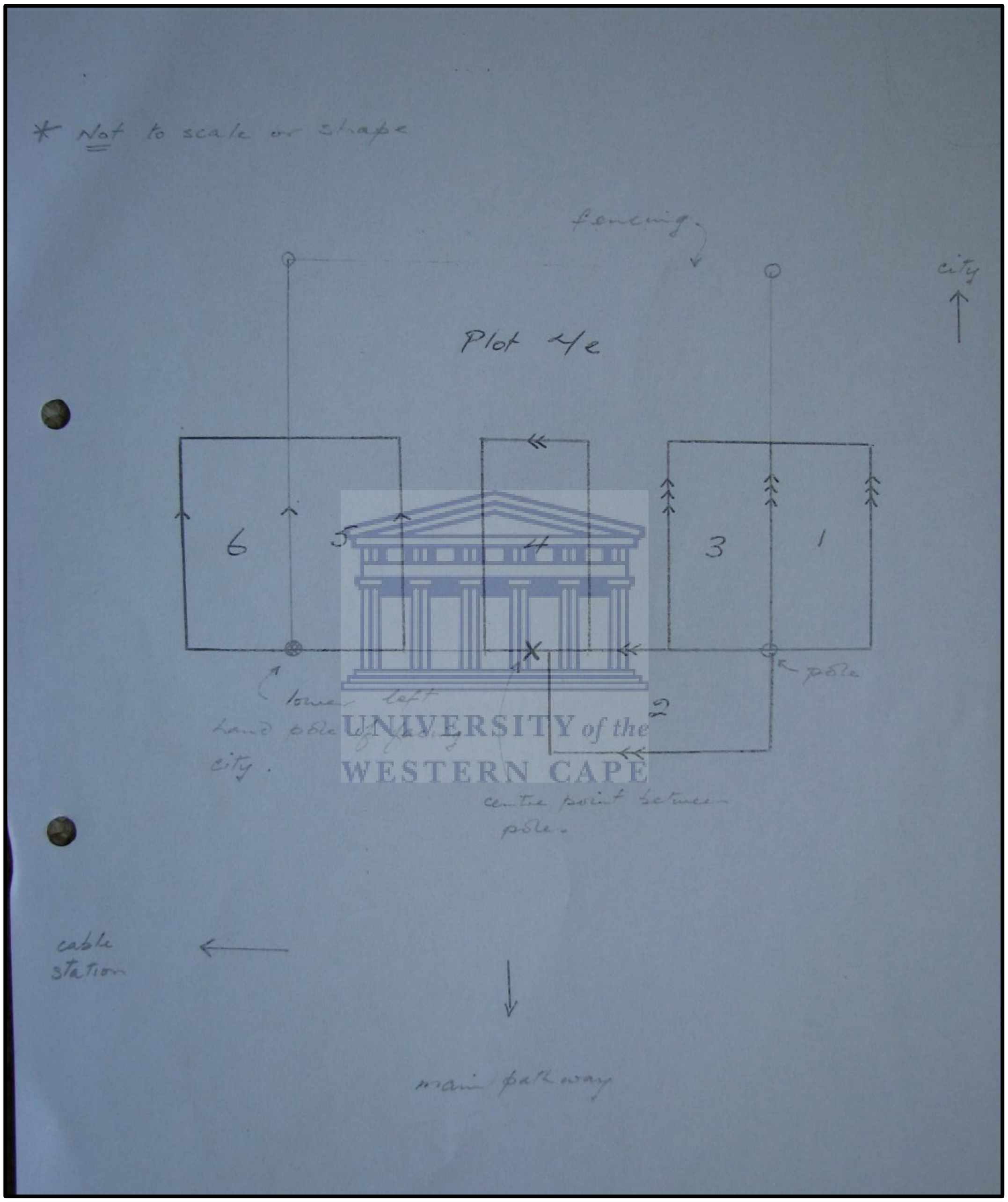
Obs	year	category	actual	estimated	plot	diff	absdiff	diff10	diff5
22	1977	Litter &	17	3	4	14	14	1	1
23	1977	Litter &	9	34	5	-25	25	1	1
26	1977	Litter &	20	35	8	-15	15	1	1
29	1977	Litter &	35	22	11	13	13	1	1
43	1977	Restioid	60	35	5	25	25	1	1
54	1977	Rock	43	55	6	-12	12	1	1
62	1977	Sand	25	40	4	-15	15	1	1
77	1988	Ericoid	20	31	9	-11	11	1	1
113	1988	Restioid	69	80	5	-11	11	1	1
114	1988	Restioid	25	11	6	14	14	1	1
117	1988	Restioid	26	15	9	11	11	1	1
125	1988	Rock	22	35	7	-13	13	1	1
162	2010	Litter &	34	20	4	14	14	1	1
163	2010	Litter &	51	65	5	-14	14	1	1
165	2010	Litter &	36	21	7	15	15	1	1
169	2010	Litter &	26	15	11	11	11	1	1
170	2010	Litter &	20	8	12	12	12	1	1
174	2010	Moss	6	20	6	-14	14	1	1
190	2010	Restioid	13	24	12	-11	11	1	1
193	2010	Rock	20	6	5	14	14	1	1

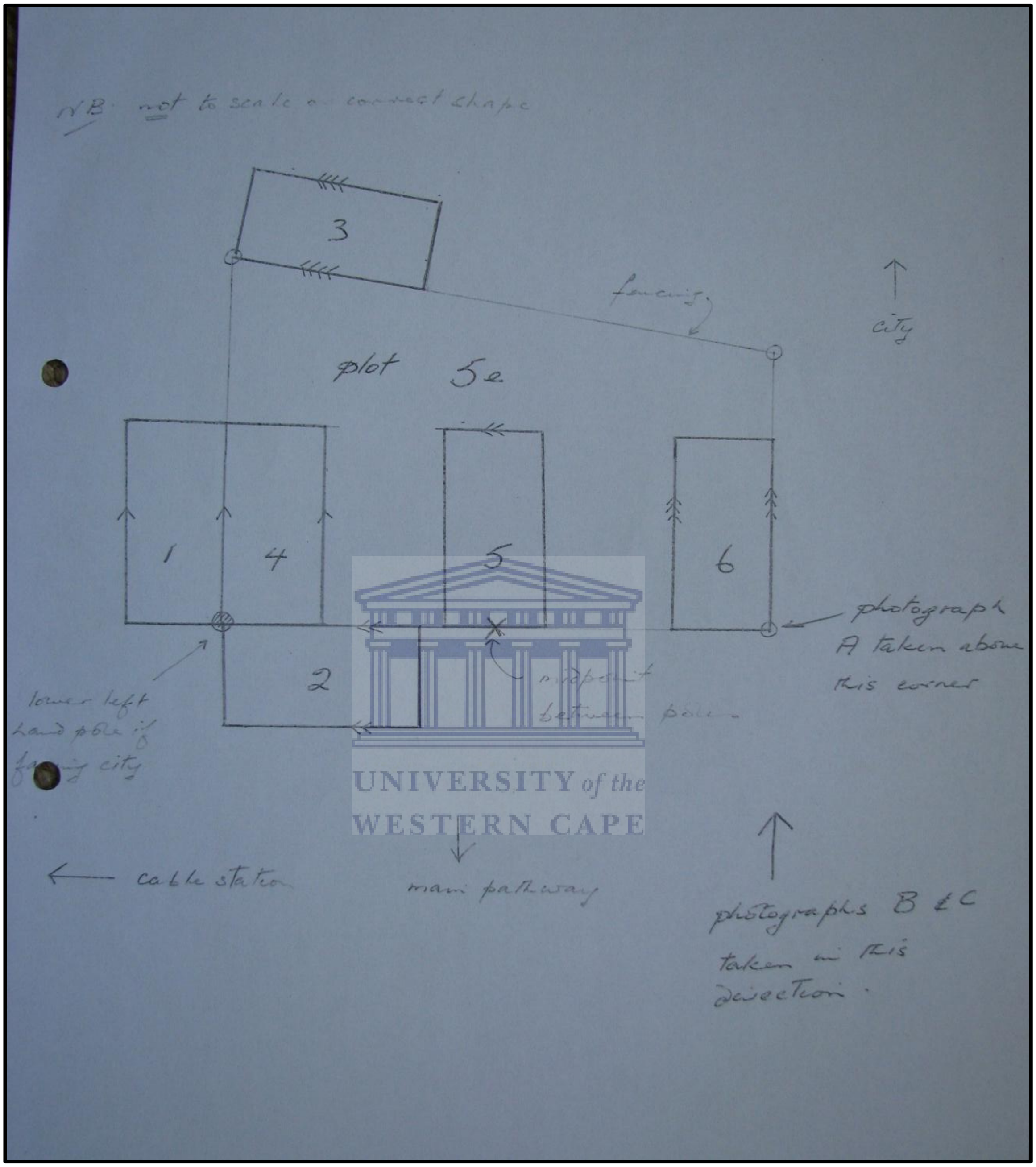
Summary of the proportion of cases differing by more than 10%

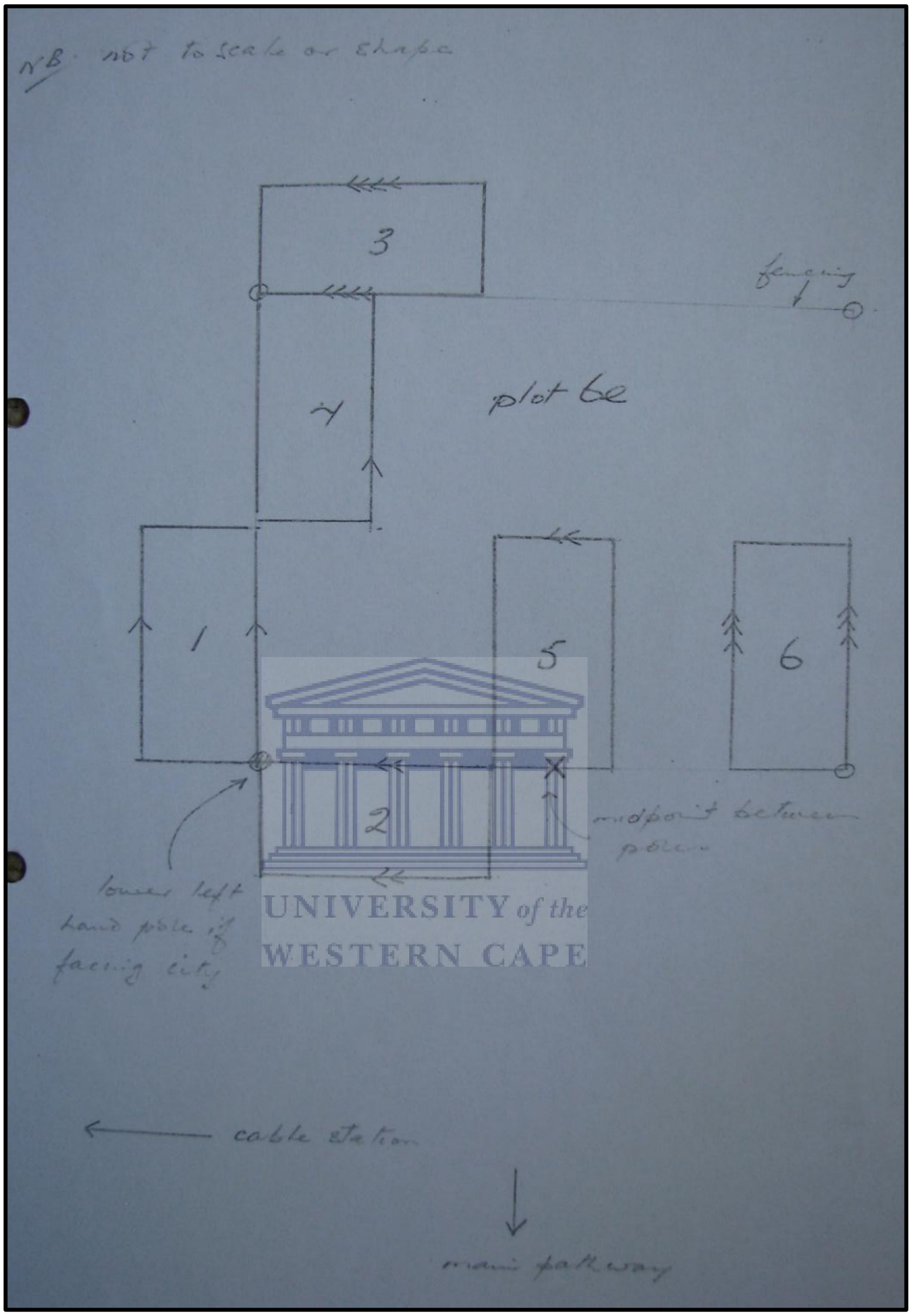
category

Frequency / Col Pct	Ericoid	Graminoi	Litter &	Moss	Restioid	Rock	Sand	Total
0	29 96.67	30 100.00	21 70.00	29 96.67	25 83.33	27 90.00	29 96.67	190
1	1 3.33	0 0.00	9 30.00	1 3.33	5 16.67	3 10.00	1 3.33	20
Total	30	30	30	30	30	30	30	210

Appendix G: Plot sampling layout for plots 4e, 5e and 6e (Coley, 1977)




NB not to scale or correct shape
3
fencing
city
plot 5e
1
4
5
6
2
photograph A taken above this corner
lower left hand pole if facing city
midpoint between poles
cable station
main pathway
photographs B & C taken in this direction.


NB. not to scale or shape
3
fencing
4
plot 6e
1
5
6
2
midpoint between poles
lower left hand pole if facing city
cable station
main pathway
UNIVERSITY of the
WESTERN CAPE