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Changes in the distribution of indigenous forest in Table Mountain National Park during the 20th Century

Z.C. Poulsen *, M.T. Hoffman

Plant Conservation Unit, Department of Biological Sciences, University of Cape Town, Rondebosch 7701, South Africa

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ABSTRACT

Long-term changes in the distribution of Western Cape Afrotemperate Forest and Western Cape Milkwood Forest in Table Mountain National Park (TMNP) were examined using paired aerial and repeat ground-based photographs. All forest patches mapped on the aerial photographs taken in 1944 and 2008 were visited and boundaries between forest and adjacent vegetation types checked in the field. In addition, 50 historical ground-based photographs covering the period 1888 to 1980 were revisited between 2011 and 2012 and the change in forest cover was quantified using a 360 point sampling grid overlaid on each of the photograph pairs.

Changes in fynbos, woody alien vegetation, alien grass, development and exposed rock and sand were also quantified. The analysis of aerial photographs showed that between 1944 and 2008 the number of forest patches on the Peninsula increased from 149 to 174 and total forest cover increased by 65.3% from 884.2 ha to 1461.5 ha. Only 13 of the forest patches decreased in cover after 1944 while 65 patches showed stasis and 96 increased in size. More than a third of the patches that decreased in size were of Western Cape Milkwood Forest located in proximity to expanding coastal development. The analysis of repeat ground-based photographs showed an increase in cover of Western Cape Afrotemperate Forest, alien grasses and urban development while fynbos vegetation, Western Cape Milkwood Forest, woody alien vegetation as well as exposed rock and sand decreased in cover. Historical land use practices such as firewood collection and a reduction in fire frequency relative to the fire regimes of the 19th century may also account for the changes observed in the historical photos. These results hold significance for the ecological management of TMNP in the face of changing climate and increased urbanisation.

1. Introduction

The world's forests are major reservoirs of terrestrial biodiversity and provide vital ecosystem services (Venter and Venter, 2009). In present debates on climate change, they are considered an integral part of climate mitigation owing to their carbon storage capacity. However, indigenous forests are under threat worldwide and the high level of global deforestation has increased the focus on effective forest conservation (Thompson et al., 2009), including in South Africa. Although indigenous forests cover only 0.56% of the land surface of South Africa (Low and Rebelo, 1996) they are among the most species-rich temperate forests worldwide (Lawes et al., 2004). How they respond to changes in climate and land use has been a matter of conservation concern for decades (Pillans, 1926; Wicht, 1945).

While not as rich in terms of plant species as neighbouring fynbos vegetation the forests of Table Mountain National Park (TMNP) are considered to be of high conservation importance (Alston and Richardson, 2006). They are home to several endemic species including two species of moss (Von Maltitz et al., 2003), numerous arthropods (Pauw and Johnson, 1999) and the Critically Endangered Table Mountain Ghost Frog (Pauw and Johnson, 1999). However, in terms of research and conservation planning, the Peninsula forests have been neglected and the current spatial extent of the Western Cape Afrotemperate Forests has not been comprehensively mapped (Von Maltitz et al., 2003). Euston-Brown et al. (2008) were commissioned by the South African National Parks (SANParks) to map the distribution of the Cape Peninsula forests. However, time and financial resources were not available to ground-truth all 212 of the forest patches that were recorded in this survey. A comprehensive assessment of the current spatial extent and distribution of the Cape Peninsula forests is, therefore, long overdue. This is crucial for effective monitoring and future conservation management of TMNP particularly in terms of the dynamics and distribution of important vegetation types such as Western Cape Afrotemperate Forest and the endangered Peninsula Granite Fynbos (Von Maltitz et al., 2003).

* Corresponding author. Tel.: +27 73 341 2430.
E-mail address: zoe.poulsen@hotmail.co.uk (Z.C. Poulsen).

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In the Cape Floristic Region (CFR) fire is an important determinant of the forest-fynbos ecotone (Manders, 1990). The frequency and intensity of fire determine whether forest patches expand or contract in size over time (Manders and Richardson, 1992; Luger and Moll, 1993). Frequent and intense fires will erode the forest edge while infrequent and cool fires or fire exclusion will enable the forest patch to expand and new forests to develop (Luger and Moll, 1993; Midgley et al., 2003).

There is currently a paucity of data available on forest distribution dynamics in TMNP. It is not known whether the Peninsula forests are undergoing change or stasis. Recent research by Forsyth and Van Wilgen (2008) suggested that fire frequency in TMNP has increased since 1975. This is significant in the face of changing climate whereby fire frequencies in the CFR are projected to increase in response to future warming and increasing aridity (Midgley et al., 2001; Bomhard et al., 2005; Hannah et al., 2005).

This has highlighted concern that the spatial extent of the Peninsula forests may decline in response to increasing fire frequencies. Such trends have been predicted in response to global change drivers in other Mediterranean climate forests in southern Europe (Morales et al., 2007). There is also the likelihood of negative impact on forest owing to predicted decreases in rainfall (Engelbrecht et al., 2008). In South Africa areas of potential forest distribution are strongly governed by moisture availability. In the winter rainfall zone, forests only occur in areas that receive more than 525 mm/yr precipitation (Von Maltitz et al., 2003).

In contrast, several authors have recently expressed concern that Western Cape Afrotemperate Forest species are invading Peninsula Granite Fynbos and Peninsula Shale Fynbos on the Cape Peninsula in response to a long term absence of fire in some areas due to expanding urban development (Rebelo et al., 2006; Rebelo et al., 2010; Van Wilgen et al., 2012). Peninsula Granite Fynbos has a high diversity of plant species with many endemic to this community. It is classified as an endangered vegetation type and 56% has already been transformed by urbanisation, vineyards and pine plantations (Rebelo et al., 2006). Colonisation by afrotemperate forest taxa would further threaten this fynbos community (Rebelo et al., 2006).

Luger and Moll (1993) used aerial photos to investigate changes in Western Cape Afrotemperate Forest distribution from 1933 to 1993 in Orange Kloof on Table Mountain. They discovered that forest had doubled in extent since 1933 and long term fire exclusion was given as the main reason for the observed changes. It remains unknown whether these trends are replicated elsewhere on the Peninsula or if this trend has continued. Here we provide further quantitative data on the distribution and temporal dynamics of the forests of the Cape Peninsula. This is vital to inform future forest and fynbos management in the TMNP. The main objectives of the study were to map the contemporary and historic distribution and spatial area of all indigenous forest on the Cape Peninsula and to examine the temporal dynamics of the forest-fynbos ecotone from 1880 to present.

2. Materials and methods

2.1. Study site

The Table Mountain National Park (TMNP) is the focal area of this study and situated on the Cape Peninsula. The Cape Peninsula is a rugged and mountainous area of 470 km^2 in size at the south-western tip of the African continent (Cowling et al., 1996). The Peninsula Mountain Chain of TMNP lies within the bounds of the City of Cape Town which is one of South Africa's largest urban areas (Anderson and O'Farrell, 2012). The Cape Peninsula is an internationally renowned centre of exceptional plant species diversity and endemism (Helme and Trinder-Smith, 2006). It is part of South Africa's Cape Floristic Region (CFR) which is a recognised biodiversity hotspot and is classified as a UNESCO World Heritage Site (Rebelo et al., 2010).

The dominant vegetation of the Cape Peninsula is fynbos, which is a Mediterranean type shrubland that is both fire prone and fire dependent (Helme and Trinder-Smith, 2006). There are three main forest types which also occur on the Peninsula: Western Cape Afrotemperate Forest, Western Cape Talus Forest and Western Cape Milkwood Forest (Von Maltitz et al., 2003; Mucina and Geldenhuys, 2006). However, for the purposes of this research Western Cape Talus Forest is considered to be a subtype of Western Cape Afrotemperate Forest. The area experiences a Mediterranean climate with predominantly winter rainfall (Cowling et al., 1996). The Cape Peninsula has exceptionally steep gradients in precipitation driven by the high topographic heterogeneity of the area (Cowling et al., 1996) (Fig. 1).

2.2. Research approach

Contact prints of aerial photographs of the Cape Peninsula from 1944 were scanned at 1000 dpi prior to georeferencing in ArcGIS 10 (ESRI, USA, Redlands). These were aligned with contemporary aerial images from 2008 to map forest change. The Euston-Brown et al. (2008) SANParks forest shapefile was used as a baseline for the study. Ground-truthing of all 212 forest patches in this shapefile was undertaken to verify the accuracy of forest/fynbos ecotonal boundaries delimited by Euston-Brown et al. (2008) and to determine whether the forest patches listed in the survey had been correctly classified. Ground-truthing was carried out from 2010 to 2012. For this analysis forest was defined as having a closed canopy greater than four metres in height and dominance of woody forest taxa (after Euston-Brown et al., 2008).

Species and cover abundance of all woody taxa were recorded for each forest patch during ground-truthing. The 2008 Euston-Brown et al. shapefile was used as a base for digitising contemporary forest distribution. It was edited or redrawn as necessary with forest patches being reshaped, added or deleted depending on the outcome of ground-truthing carried out over the period 2010–2012. The contemporary forest distribution shapefile was then used as a baseline in conjunction with sets of historical aerial photographs to produce another shapefile delimiting forest distribution on the Peninsula in 1944. These were both then used to measure change in forest distribution and extent between 1944 and 2008 using ArcGIS 10.

For the ground-based repeat photography study, 50 historical images showing Western Cape Afrotemperate Forest and Western Cape Milkwood Forest on the Peninsula were used in the analysis of forest cover change (Appendix I). The historical photographs covered the period 1882 to 1980. The location of each historic image was relocated in the field between 2010 and 2012 and a replicate image was taken. The repeat and original images were matched as closely as possible using Adobe Photoshop CS4. The complete ground-based repeat photo collection together with associated metadata (primarily photo number, site name, GPS coordinates, altitude, photographic information, geology, landforms, vegetation types, description of main changes and detailed species lists with estimated percentage cover values) was then used to investigate land cover change on the Cape Peninsula. In the analysis we focussed on the temporal change in the distribution of Western Cape Afrotemperate Forest and Western Cape Milkwood Forest.

To do this, the ground-based photographs were subdivided according to forest type and date of the original photograph (historic images prior to 1970 and more recent photos) and then analysed separately. A 360 point grid was placed over each image in Adobe Photoshop CS4. At each gridline intersection the land cover type was recorded and assigned to a land cover class of either Western Cape Afrotemperate Forest, Western Cape Milkwood Forest, fynbos, woody alien vegetation, alien grass, development and exposed rock and sand. Sky and sea were