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Proposed long-term monitoring protocol and applications for *Aloidendron dichotomum* populations

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ABSTRACT

The iconic succulent tree, *Aloidendron dichotomum*, is found throughout the arid and semi-arid parts of South Africa and Namibia. It has been suggested as a climate change indicator species with long-term monitoring of populations initiated by various institutions in order to improve understanding of its population dynamics and main climate drivers. This proposed monitoring protocol attempts to combine various methodologies already used in order to standardise on field data collection procedures. In order to illustrate the value of the data collected this paper compares baseline demographic data recorded for 12 populations across the Northern Cape (South Africa). Live and dead tree densities were highly variable across populations. Size class distribution (SCD) analysis using height classes and basal diameter classes resulted in different population curve types depending on the variable plotted emphasising the importance of variable choice.

Comparison of the midpoint of the basal diameter classes and the natural logarithm of density of individuals per class indicated different linear regression slopes for the Kokerboomkloof population and eight other populations and in one instance, the Kokerboomkloof intercept value differed. In all populations, the calculated centroid value was smaller than the median indicating growing populations.

The low occurrence of leaf fungi and scale as well as damage to leaves and stems, indicate that populations are generally healthy with regard to pests and disease. Percentage live and dead heads, dead canopy and dead trunks for surveyed trees were highly variable across populations.

At present, the 12 surveyed South African *A. dichotomum* populations appear to be in good health and are recruiting. Our study highlights that the choice of population surveyed is of importance and that a wide range of populations in close proximity to one another and at different sites situated far apart have to be surveyed in order to produce an unbiased assessment of populations.

1. Introduction

Aloidendron dichotomum, previously *Aloe dichotoma*, is a widespread and iconic succulent tree species distributed across the arid and semi-arid winter and summer rainfall regions of Namibia and South Africa (Jack et al., 2014). This distinctive tree aloe is between 3 and 9 m tall, often densely rounded as a result of repeated forked branches ending in relatively small terminal rosettes (Klopper and Smith, 2007) (Supplementary Fig. 1). Inflorescences are short, erect and branched with three to five flowers heads. Bright yellow flowers are produced between June and August (Klopper and Smith, 2007). The species has a winged diaspore with the capability of increased dispersal distances (Cousins and Witkowski, 2012). It has an estimated recruitment frequency of 15 years (Foden et al., 2007) and long lifespan (Burke, 2004) of up to 250 years (Kaleme, 2003). Kaleme (2003) estimates that fast growth occurs during the first 50 years of the life of the plant. Dead individuals decay relatively slowly in situ (Foden et al., 2007; Jack, 2011).

The species is found on numerous inselbergs in the Nama- and Succulent Karoo biomes and was listed by Burke (2004) as one of 25 plant species that would be suitable candidates for monitoring climate change impacts in areas where complete biological inventories are lacking. Numerous studies over the last 20 years have highlighted large-scale mortality for *Aloidendron dichotomum* at various localities in Namibia and South Africa. Local mortality in various populations has been attributed to animals (Midgley et al., 1997), disease (Foden et al., 2007), windthrow (Jack et al., 2014), theft (Van Blerk, 2013) and climate change (Foden et al., 2007; Midgley et al., 2007). Recently, it has been found that mortality and recruitment patterns reflect prevailing differences in the summer rainfall zone (Nama Karoo Biome) and winter rainfall zone (Succulent Karoo Biome) climates (Jack et al., 2016).

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The Succulent Karoo Biome is a winter-rainfall semi-desert region with a Mean Annual Precipitation (MAP) of between 100 and 200 mm (Mucina et al., 2006a). A complex geology underlies this Biome and, depending on locality, varies from volcanic and sedimentary rocks or mosaics of both. Most of the endemic genera of the Biome are either succulents or geophytes and the high diversity of dwarf leaf succulent shrubs is the biome's most distinctive characteristic. The Nama Karoo Biome is an arid biome with a MAP ranging between 70 and 500 mm with most rain falling in late summer (Mucina et al., 2006b). The low rainfall is unreliable with unpredictable and sometimes prolonged droughts. Underlying the Nama Karoo Biome is a succession of sedimentary rocks of the Karoo Supergroup that includes Dwyka tillites and Ecca Shales, as well as igneous intrusions. Nama Karoo vegetation is dominated by dwarf shrubs and grasses and is not particularly species rich with low local endemism.

Systematic observations of *A. dichotomum* could provide a sensitive test for projections by monitoring species turnover in time, with the added benefit of revealing the demographic processes that accompany range shifts (Midgley et al., 2007). Baseline data collection has in recent years been initiated throughout the Nama- and Succulent Karoo regions of South Africa and Namibia by various organisations including the Northern Cape Department of Environment and Nature Conservation (DENC), South African National Parks (SANParks), the University of Cape Town (UCT) and the South African Environmental Observation Network (SAEON). A concerted effort by researchers of these organisations to standardise methodology has begun. Our paper provides an approach that could be used in future in order to produce data sets that can be compared over time as well as between populations at different localities.

The current paper illustrates the value of the demographic data collected using the proposed methodology for 12 *A. dichotomum* populations across the arid and semi-arid Northern Cape province of South Africa. Eight populations within the Nama Karoo Biome and four populations within the Succulent Karoo Biome, spread throughout the natural distribution range of *A. dichotomum* across the province, were investigated and compared. A standardised methodology is outlined and analytical approaches presented.

2. Materials and methods

2.1. Field surveys

The eight summer rainfall Nama Karoo *Aloidendron dichotomum* populations studied are situated in the vicinity of the towns of Klein Pella (Klein Pella), Augrabies (Zwaartkop), Prieska (Kliphuis), Kenhardt (Kenhardt) and Carnarvon (SKA 1–SKA 4) (Fig. 1). The four winter rainfall Succulent Karoo populations are located in the vicinity of Sendelingsdrift (Kokerboomkloof), Springbok (Goegap Nature Reserve), Kamieskroon (Nourivier) and Nieuwoudtville (Gannabos).

All the *A. dichotomum* populations surveyed form part of long-term monitoring projects initiated by the South African Environmental Observation Network (SAEON) or the Department of Environment and Nature Conservation of the Northern Cape (DENC). Eight populations were surveyed by DENC between 2010 and 2013. The remaining four populations were surveyed by SAEON in 2015 and are situated within the Square Kilometre Array (SKA) astronomical observatory core area (SKA 1–SKA 4 on Fig. 1). Three of these SKA populations are situated within 4 km of one another, while the fourth population is situated about 13 km away from the cluster of three. These populations are situated at the south-eastern end of the *A. dichotomum* distribution range and in a botanically unexplored section of the Nama Karoo Biome. The DENC populations were specifically selected on the basis of the relatively large size of the populations. Two surveys were conducted in each population. These were a general population density and mortality survey, as well as a more detailed demographic survey.

A 1000 m × 4 m belt transect that traversed the densest part of the population (and included the demographic survey plot) was

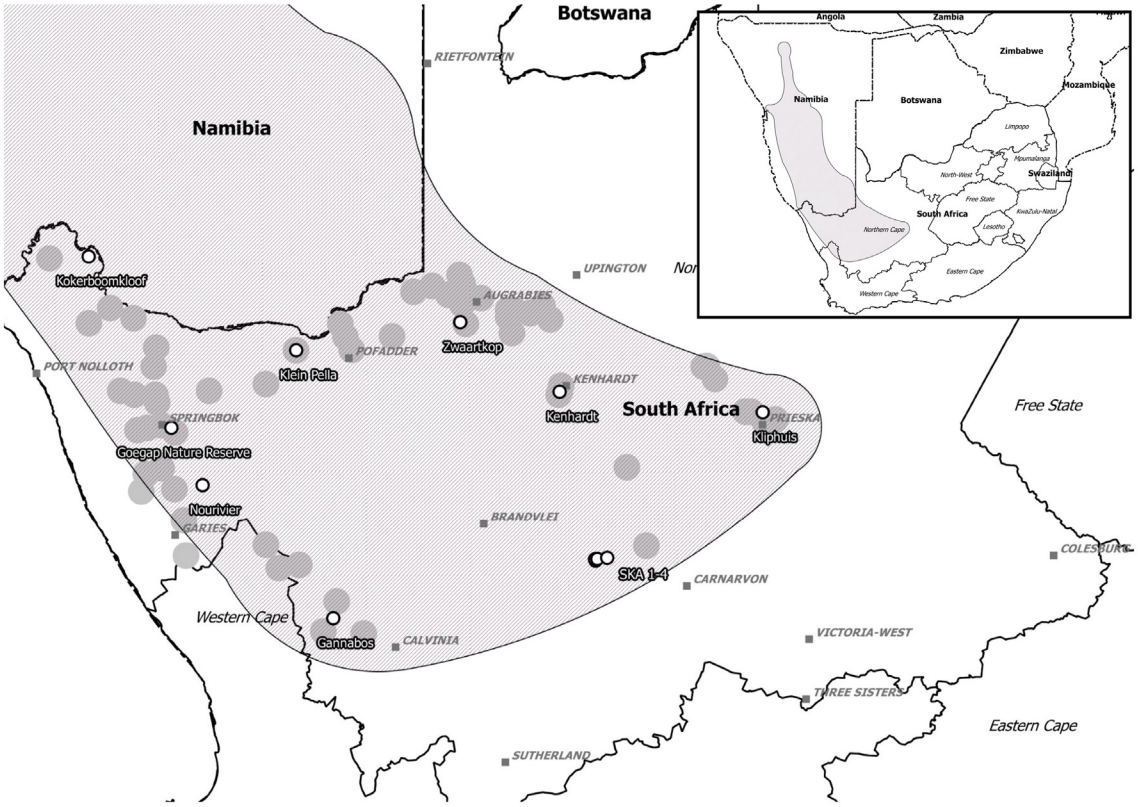

Fig. 1. Map indicating the *Aloidendron dichotomum* populations surveyed in this study (white circles).