Estimating Vegetation Change in Saadani National Park

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Abstract Maintenance of species diversity is one of the prime objectives of establishing protected areas network and the main responsibility of wildlife managers. We report results of the study which aimed at estimating vegetation change in Saadani National Park. Specifically, we determined abundance in terms of relative density and variation in diversity between old and regenerating tree populations. Data were collected using a Point Centered Quarter method. A total of 800 trees were measured. Results revealed significant variation in species diversity between regenerating and the old tree populations (F = 8.146, P < 0.01). The relative density of regenerating Acacia zanzibarica was (77%) and Terminalia spinosa (12%) respectively and higher than the corresponding old population with (65.5%) and (7.75%) respectively. We recommend mechanical removal and efficient use of fire to prevent establishment of A. zanzibarica seedlings and saplings in order to decrease its competitive dominance while promote the establishment of new tree species. Conversely, management should look into the possibility of introducing medium sized browsers like impala in order to reduce recruitment rate of A zanzibarica. Further to that, we recommend establishment of a long term vegetation monitoring study which will detect spatio-temporal patterns of vegetation changes and the possible drivers.

Keywords Abundance; Dominance; Regenerating trees; Relative density; Species diversity; Saadani National Park

1 Introduction

Tropical savannas are dynamic ecosystems alternating between woodland and grassland communities (Sinclair and Arcese, 1995). The balance between grassland and woodland is controlled by complex interactions between edaphic and climate factors (Higgins et al., 2000; Fuhlendorf et al. 2008), elephant (Laws, 1970; Myers, 1973; Caughley, 1976; Pellew, 1983), fire (Dublin et al., 1990), grazing (Riginos and Young 2007) and browsing pressure (Prins and Van der Jeugd, 1993). Variations in any of these factors can induce change in proportion of woody and herbaceous which in turn affect vegetation structure, ecosystem function, primary productivity, plant diversity and abundance as well as associated animal communities.

Plant abundance and diversity are among important attributes of community organization (Shaukat et al, 1978). Plant abundance is a measure of plant numbers in a site (Hanski, 1982), whereas species diversity is an index of diversity within an ecological community that incorporates both species richness which is the number of species in a given area or a given sample and the evenness of species' abundances (Spellerberg and Fedor, 2003). For many years ecologists have been using plant abundance (cover, frequency, density and biomasses) and plant diversity (species richness and species evenness) to quantify amount of vegetation changes. In Saadani National Park, Acacia zanzibarica is an indigenous tree species that seems to be the most competitive dominant species in the park. The species has extended to areas that were historically grasslands. This has reduced the area available for grazing animal and restricting smooth movement of animals in the park. The risk of vegetation changes in Saadani National Park has been reported for more than a decade now (Bloesch and Klötztli, 2002; Augustine, 2003; Tobler et al., 2003; Treydte, 2004), to date no study has been conducted to quantify amount of vegetation change in the area.

The study aimed at estimating vegetation change in Saadani National Park. Specifically, we determined abundance in terms of relative density and variation in species diversity between the old and regenerating tree populations. We hypothesize that regenerating tree population have lower species diversity than the old tree population. Findings from this study will inform managers on the current vegetation status and suggest appropriate measures which can
be taken to maintain ecological integrity of the park.

2 Materials and Methods

2.1 Study area description

The study site is found on the South Eastern part of Saadani National Park in Bagamoyo District, Coast Region. The park is located at 6°00'S 38°45'E (Figure 1). The park covers a total area of 1100 km² and was officially gazetted in 2005 from a game reserve which had existed from 1969. The climate is coastal, hot and humid which offers a unique combination of both marine and mainland flora and fauna. About 30 species of larger mammals are present as well as numerous reptiles and birds. Some species of mammals include: Elephant (*Loxodonta africana*), Hartebeest (*Alcelaphus buselaphus*), African Buffalo (*Syncerus caffer*), Waterbuck (*Kobus ellipsiprymnus*), Bohor Reedbuck (*Redunca redunca*), Giraffe (*Giraffa camelopardalis*), Warthogs (*Phacochoerus africanus*), Yellow baboon (*Papio cynocephalus*), Red Duiker (*Cephalophus harrvayi*), Grey Duiker (*Sylvicapra grimmia*), Bushbuck (*Tragelaphus scriptus*), Wildebeest (*Connochaetes taurinus*), Common Zebra (*Equus quagga*) as well as predators such as the Lion (*Panthera leo*) and Leopard (*Panthera pardus*).

Rainfall is bimodal and annual precipitation ranges from 500 to 1 700 mm, with a mean of around 900 mm (Cochard and Edwards, 2011). Short rains usually fall from October to December whereas long rains fall from March to early June (Cochard and Edwards, 2011).

2.2 Data collection

This study was conducted in November 2014, in which a total of 100 plot-less points were established and 800 hundred trees having height of more than 2 m were sampled. The study was designed in such a way that we had ten transect replicates each spaced at 700 m apart. Each transect had a length of 1km from the baseline (Wami River - Chumvini village road) and we employed systematic sampling design to position ten points on each transect. After establishing the first plot less point randomly from the baseline, we established nine replicates on each transect after every 100m running from east to west. From each plot-less point we sampled 8 trees, two from each of the four quarters/quadrants of a PCQ cross bar. In each of the quarters of a PCQ bar the circumference of two trees were measured at a breast height (i.e. 130 cm from the ground) using a standard tape measure and recorded. Trees with circumference at breast height (CBH) lower than 20cms represented "regenerating tree" and greater or equal to 20 cm represented "old trees". We also measured and recorded a point to the nearest tree distance in meters. In order to estimate the amount of vegetation change we determined relative density as it is robust to seasonal changes and species diversity which is sensitive to alteration.

2.3 Data analysis
2.3.1 Relative density
The recorded raw data were transcribed into the Ms Excel computer program, summarized and used to calculate the relative density for each tree species. We used Ms. Excel to plot histograms of trees' relative density against tree species. The aim was to compare descriptively relative density of old and regenerating tree populations.

2.3.2 Trees species diversity
Ms Excel computer program was used to calculate Shannon diversity indices and R statistics was used to analyze the diversity indices against tree stages. Response for this model was Shannon diversity index which is a continuous variable with trees stages as categorical variable. The predictor possessed of two categories that is tree species with Circumference at Breast Height (CBH) greater or equal to 20cm and trees with CBH less than 20cm. This response distribution and predictor type necessitated the use of linear model. This type of model requires linear relationship between variables, homoskedasticity, normal distribution of response and independence of observation. We used hist. command in R to test normality of response and noted that variables were fairly normal distributed. Furthermore we used box plot to visualize median and data spread (Zuur et al., 2010) and found that one observation fall outside the normal range of data hence an outlier. To curb the effect of the outlier we used median which is robust to outliers' effect. We plotted the median using box plot to report biological significance and ANOVA was used to determine statistical significance level.

3 Results
A total of 800 trees were measured and analyzed in our study. Out of these trees, 400 trees had Circumference at Breast Height less than 20m which represent "regenerating tree" population and 400 trees had Circumference at Breast Height greater or equal to 20cm representing "old tree" population.

3.1 Relative density
Results reveal that only regenerating tree population of *Acacia zanzibarica* and *Terminalia spinosa* have higher relative density than old tree populations of the same. Conversely, regenerating tree population of the remaining species have lower (or similar) relative density than their corresponding old populations (Figure 2).

3.2 Trees species diversity
Results reveal significant variation in species diversity between regenerating and the old tree populations (Figure 3).

4 Remarks
Results show relative density of regenerating *Acacia zanzibarica* and *Acacia mellifera* is higher than corresponding old trees population. On the other hand, results show significant variation in species diversity between regenerating and the old tree populations as hypothesized.

More than three quarter of the regenerating tree population is dominated by *A. zanzibarica*. Reduction of hot fires, grazing history and heavy loamy-clayey soils are said to have influenced establishment and spread of *A. zanzibarica* (Cochard and Edwards, 2011). Similarly, absence of medium-sized browsers like impala probably explains high recruitment rate and establishment of *A. zanzibarica* woodland (Prins and Van der Jeugd, 1993). Prins and Van der Jeugd (1993) urged that with high browsing pressure by impala and other small-medium browsers, establishment of *Acacia* seedling is rare and this impact declines with tree maturation as most foliage of a mature tree grows beyond reach of these browsers. Establishment of *A. zanzibarica* woodland to such extent in the study area significantly reduces grazing resources available to wildlife (Cochard and Edwards, 2011), provide a suitable habitat for tsetse flies (Trail et al. 1985) and block passage of large bodied animals thus restrict the use of the area. It has also been observed that dominance correlates negatively to measures of species diversity (Braun, 1950; Whittaker, 1965; McNaughton, 1968; Berger and Parker, 1970). Therefore, the ultimate negative effect of dominance of *A. zanzibarica* in the study area is to cause a decline in plant and associated animals diversity.

Our study reveals significant variation in species diversity between regenerating and the old tree populations. Results have shown that old tree population has higher diversity than regenerating population suggesting diversity...
of regenerating tree population is declining. Many factors could have contributed to this decline of species diversity in the study area, some of the possible factors include but not limited to competitive exclusion and low level of disturbance (Whittaker, 1975; Connell, 1978; Huston, 1979; Peterson and Reich, 2008). Connell (1978) and Huston (1979) studies provide linkages between disturbance frequency and species diversity. It appears that in the study area, A. zanzibarica is a competitive dominant species over the other species. Being nitrogen fixer, absence of medium-sized browsers (Prins and Van der Jeugd, 1993), seed dispersal mechanism, reduction of hot fires, grazing history and presence of heavy loamy-clay soils (Cochard and Edwards, 2011) are some of competitive advantages of A. zanzibarica in the study area. Many studies have shown positive correlations between terrestrial animal and plant diversity (MacArthur and MacArthur, 1961; Murdoch et al., 1972; Willson, 1974). This implies that reduction in plant species diversity in the study area will have a negative influence on the animal’s species diversity simply because plants provide different habitat types, food and other key resources (Lawton, 1994).

Figure 2 Relative density of regenerating and old trees' populations

Figure 3 Variation in Shannon Diversity Indices between trees with CBH ≥20cm (old tree population) and trees with CBH < 20cm (regenerating tree population)

Note: F_{1,18} 8.146, P < 0.01

5 Management Implications

Maintenance of species diversity is one of the prime objectives of establishing protected areas network and the main responsibility of wildlife managers. Despite the fact that our study had a limited coverage, we have managed to show empirically that A. zanzibarica dominates and tree species diversity decline significantly in the study area. A. zanzibarica is an indigenous tree species in Saadani National park which seems to be competitive dominant species over other species and which has now extended to areas which historically were grasslands. We therefore propose immediate measures to be taken to curb and reverse this vegetation transformation. This study recommends efficient
use of fire to prevent establishment of A. zanzibarica seedlings and saplings in order to decrease its competitive dominance while promote establishment of other tree species. In addition to that, we recommend clearing of A. zanzibarica in order to reduce its dominance and open a way for establishment of other species. On top of that, we recommend establishment of a long term vegetation monitoring study in order to detect spatial-temporal patterns of vegetation changes and the possible drivers. Furthermore, management should look on the possibility to introduce medium sized browsers like impala in order to reduce recruitment rate of A. zanzibarica.

Author’s contribution

Henry K. Njou and Ladislaus.W. Kahana designed and conducted the experiment and write up. Elizabeth Kamili, Gideon Alfreld and Rudolf Mremi did data analysis and write up. All authors read and approved the final manuscript.

Acknowledgements

We greatly thank the College of African Wildlife Management, Mweka for financing this study. We also thank Tanzania National Parks granting permission to carry out this important study in Saadani National Park. Furthermore, it is worth noting that this study would not have been completed without 2014/2015 Diploma Year One Wildlife Management Students.

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