Setting the Thresholds of Potential Concern relating to plant and animal dynamics

Overview

These TPCs are at both the landscape as well as, where possible, the catenal level scale. The TPCs will be calibrated differently for the different sensitivities of the landscapes. We consider the biodiversity elements in the following way:

Composition

Decline of the least dominant component (vegetation and herbivores, separately)

Decline of the important*, dominant and any threatened species (vegetation and herbivores, separately) *defined as any or all of "diagnostic", "charismatic", "characteristic", "keystone", "indicator" or "sensitive" species.

Structure and Function

Shift in abundance from the bench mark/theoretical threshold

Grass will be dealt with by looking at a matrix of annual/perennial and palatable/unpalatable species

Regeneration - measured as small woody plants, with concern triggered if they are tending to zero(concerns about seedlings will be dealt with by specific research projects)

Large woody plants (= large tree component) - concern triggered when they tend to zero

Loss of either the browser or grazer component - concern triggered when either of these tend to zero

The NDVI to rainfall relationship - concern with any persistent significant deflection in the slope of the relationship from the expected.

Some themes are dealt with under this heading and again under the spatial heterogeneity heading. There is still a fair amount of overlap in these two TPC approaches and we will reduce this as soon as we are confident with the performance of the heterogeneity TPC.

Rationale

Shifts in composition of the woody plants in KNP

Woody plants are understood to contribute to the indigenous biodiversity in KNP in a number of ways (Pickett et al. 2003). Shifts in the composition of woody plant communities are understood to be indicative of a fundamental shift in the system as a whole. These compositional shifts can be absolute i.e. local extinction of a species, or relative in which case the ratios of species abundances change. Both types of change can have implications for biodiversity conservation. 1) The local extinction of a species is clearly of significance in the context of biodiversity conservation particularly if the protected area from where it is lost is an important refugium for the global population of that species. 2) A shift in relative abundance of dominant species can also be significant. For example in Hluhluwe-Umfolozi Park, the shift in dominance from Acacia nilotica woodlands (with a dense and extensive canopy which creates a shaded habitat, commonly with a short grass under storey due to the resultant increased grazing pressure (Bond et al. 2001)) to A. karroo dominated woodlands (with a less dense canopy and resultant longer grass habitat) is likely to favour different large mammal herbivores (du Toit 2003) as well as bird species (Skowno 2001; Kemp et al. 2003). 3) A decline in the relative abundance of non-dominant species can be important as it can be used as early warning for potential local extinction, particularly as these are often rare and thus species of conservation significance.

Not all species necessarily carry equal weighting in a particular protected area and for various reasons some are given greater emphasis than others. These are nominally called “important” species with this category including species that are variously called “diagnostic”, “charismatic”, “characteristic”, “keystone”, “indicator” or “sensitive”, based on technical, societal-value or other reasons.

Shifts in structure of the woody plants in KNP

Under the “structural” heading, we consider only vertical structure as the horizontal structure of the woody plants is captured under the “Heterogeneity” element of concern. Shifts in the structure of woody plant communities in savanna ecosystems have been widely documented. The structure of woody plants in savannas is important as different woody plant structures can be seen as surrogate measures for different elements of the indigenous biodiversity (Kemp et al. 2003; and see Pickett et al. 2003). Because of the biodiversity consequences, a shift in woody plant structure from any one size class to another is of interest, but because they form the smallest abundance class, tall trees are commonly of more interest. In addition they may contain limited or less common surrogacy features linked to successional maturity (e.g. certain birds may only be associated with tall trees and if the trees disappear, the birds disappear). For this reason much emphasis is placed on loss of tall trees, while retaining the need to understand the shifts in abundance of lower height classes of woody plants.

In African savanna systems the shift from taller trees to shorter trees or shrubs are commonly attributed to fire or elephant (e.g. Pellew 1983), but can also be a consequence of browsing by other herbivores such as giraffe (Bond & Loffell 2001), or porcupine (Yeaton 1988) as well as other factors such as high winds, disease, flood (Rogers & O’Keeffe 2003) or drought (Viljoen 1995, Shackleton 1998) or, probably more commonly, a combination of these. As generalities are difficult too draw – e.g. the loss of tall trees in east Africa has been documented to be a result of fire (Dublin et al. 1990) and elephant (Laws 1970) – it is important that each case is evaluated on its own. In the case of KNP it is useful to note that, to date, there is little indication that the Serengeti experience, of fire alone reducing the number and height of tall trees (Dublin et al. 1990), occurs. Rather indications are that away from the riverine habitat, elephant (at times possibly followed by fire) may provide an important disturbance in this regard (Eckhardt et al. 2000, Scholes et al. 2003) and there may be knock-on biodiversity consequences at high enough elephant densities (Cumming et al. 1997) although this relationship has not been established.

However the evidence, although not equivocal, remains inconclusive and there is an urgent need to understand the causes of changes in the abundance of tall (> 5m) trees as well as other size classes. For example a significant increase in the abundance of trees in the 3 to 5m class indicates the potential for future tall trees, while a similar increase in the less than 3m size class may indicate an encroachment event with important biodiversity implications. An important distinction that needs to be made in the less than 1m class is whether an individual is resprouting or is a seedling (see Balfour 2005).

Shifts in system function following shifts in the woody plant dynamics in KNP

In addition to contributing toward the compositional and structural diversity of KNP, woody plants play a number of roles in the ecosystem functioning such as hydraulic lift (Ludwig 2001), erosion control on river margins (Rogers & O'Keeffe 2003) habitat for different herbaceous species (Scholes & Archer 1997), nesting and perching sites for birds and others. In light of the unknown magnitude as well as the complexity of these functions it is not possible at this stage to set TPCs for any of them although it is important to bear them in mind for future reference.

Shifts in system functions following shifts in the herbaceous plant dynamics in KNP

The fundamental principle for determining TPC's for the grass sward is the relation between the soil production potential and rainfall on the one hand, and the composition and production (standing crop) on the other. Composition is important as far as it relates to overall soil stability or vulnerability to erosion (perennial-annual-bare ground relations). Consequently, the basic rationale is that if the basal cover does not correspond with the expected potential of the soil to produce a herbaceous layer, taking the modifying effects of rainfall into account, this would trigger a TPC.

The soil production potential of the soil series of SA was determined by Edwards & Scotney (1978). This provides a very useful basis for rating the production potential of the soils of the KNP via the information presented by Venter (1990). This information is used to determine the production potential of each land type and for each hillslope unit within a particular land type. The setting of TPC's is then simply based on the comparison of the expected and actual composition of each of these units. The proportion of each dominant soil series for each hillslope unit in each of the 56 land types (Venter 1990) will be used to weight the production potential of Edwards & Scotney (1978) to produce an overall production potential score for the land type as a whole. The threshold outlined below illustrates approximate ('first-stab') thresholds for composition, standing crop and bare ground, relative to the preceding three years' annual rainfall totals.

Shifts in large herbivore distribution and composition

Herbivores are important drivers of savanna ecosystems and utilize up to 30 – 60% of primary production (Crawley 1983; McNaughton et al. 1989; Senft et.al 1983). Herbivores also utilize the landscape differently depending on their body size (Du Toit & Owen-Smith 1989; Du Toit & Fritz 2003; Owen-Smith 1988), and hence have been classified according to their utilization by Collinson & Goodman (1982). More heavily utilized patches will give an earlier indication of degradation or over utilization than randomly selected sites and a herbaceous TPC should be exceeded in these areas before any of the less utilized patches if herbivores are the cause of exceedance.

Ideally, the heterogeneity/aggregation TPC should account for herbivory, but as this TPC is still under development some specific herbivore TPCs will be maintained to be able to track changes in herbivore distribution and composition. There is still a fair amount of overlap in these two TPCs and we will reduce this as soon as we are confident with the performance of the heterogeneity TPC.

These TPC's are set at both the landscape as well as where possible the catenal level scale. At this stage we do not have the capacity to look at herbivore distribution at the catenal scale but we hope to use cyber-tracker sightings as well as dung distribution (Barnes 2001; Plumtree 2000).

The TPC's will be calibrated differently for the different sensitivities of the landscapes and we consider the following aspects:

Decline of the least dominant component.

The decline of the least dominant component is seen as the most sensitive indicator of a species change due to environment or other changes. It is thus considered important to detect such a change in herbivore composition independent of whether the particular species or group is threatened. The decline in the selective grazers in the KNP is probably an example of such a group indicating system change (Grant et al. 2002)

Decline of the characteristic, dominant and any threatened species may indicate system change (Grant et al. 2002; Ogutu & Owen-Smith 2003; Owen-Smith 1997; Owen-Smith 1985)

Loss or change of the functional component

Loss of either the browser or grazer component will indicate a change in available resources. As an example, the change that has occurred in elephant diet reflects a system change (Codron et al. 2006). Changes from browsers or selective grazers to mixed feeders such as a change from bushbuck being dominant to nyala being dominant will also indicate a system change.

Change in the range of herbivores could also indicate a system change as herbivores are dependent on specific nutritional and habitat resources that are linked to ecosystem processes (e.g. Wentzel et al. 1991; Botkin et al. 1978; Naiman et al. 2003). Herbivore distribution may change due to burnt areas and areas of higher rainfall. Therefore this TPC is based on a 7/13 years occupancy during the period when total aerial counts were done, as baseline.

Work done by Mills et al. (1993) in the KNP identified significant rainfall related population trends in kudu, waterbuck and buffalo. We propose that a significant change in trend over three consecutive years will indicate a system change that should be further examined.

Relation to KNP objectives

Primary production (carbon assimilation by plants through photosynthesis) is an important ecosystem parameter conventionally expressed as dry-matter production over a given period of time (Scholes & Walker 1993). Because of the close relationship between carbon assimilation and primary production, the effects of global climate change and increasing levels of CO_2 in the atmosphere can be expected to be reflected in primary production. In addition, since primary productivity plays a fundamental role as food and habitat for a wide variety of organisms, as well as fuel for fire, a measure of primary production and its spatial and temporal distribution provides essential basic information for the better understanding of the functioning of the ecosystem in general.

The Competition and Community Dynamics Objectives place emphasis on processes and how different biotic components interact with each other at the community level. The main focus is on understanding the actual processes in terms of actions and reactions, or responses, between the different components of communities and also between these and the abiotic environment. Understanding the major ecological processes calls for a systems approach rather than a species approach. Communities consist of individuals of several species and the interaction between these differs from one to the next. Our aim is to allow such variation and to ensure that significant patches do not disappear.

The herbivory objective is to understand the role of herbivory as a modifier of heterogeneity and biodiversity in the KNP ecosystem by understanding the processes and scales at which herbivores operate and how they affect and respond to heterogeneity and biodiversity. This objective deals more with the effects of vegetation utilization by herbivores than with herbivore components themselves. These effects should be the decisive factor determining the way in which elephants will be managed in the KNP. The detection of vegetation changes will be covered by the vegetation and the heterogeneity/aggregation TPCs, but the effect of elephant utilization on the distribution and the utilization of the landscape by other herbivores will be covered by the large herbivore TPCs proposed. At this stage there is no specific TPC linked to utilization of vegetation by elephant or any other species as the concern is about the outcome and not about the utilization per se. However, information on utilization by different herbivores will have to be collected to be able to inform the vegetation TPCs of causal mechanisms. This TPC should also address herbivory by invertebrates such as termites which have been proven to be ecosystem engineers (Dangerfield et al. 1998), and has had very little attention thus far.

Monitoring implications

TPCs invoke monitoring programs which aim to detect shifts in species composition for the woody component of the vegetation of KNP. Ecological factors which are anticipated to contribute toward these shifts and which the monitoring programs should be able to shed light on, include fire regime (mainly frequency and intensity; van Wilgen et al. 2003) herbivory (mainly small herbivores feeding on seedlings and the recruitment phase e.g. Prins & van der Jeugd 1993) and elephant activity resulting in the loss of reproductively mature individuals from the population (see structural shifts below).

TPCs have also been set which invoke monitoring programs which will enable the detection of shifts in woody plant structure and in particular they are aimed at being sensitive toward the loss of large trees. The spatial scales of the TPCs for structural shifts are explicit in that they refer to the protected area as a whole or to a specific land unit (e.g. specified landscapes) within KNP. These monitoring program aims to be able to indicate which factors are driving the shift in woody plant structure but they may not be adequate and will require associated research programs to assist with better understanding the causative factors.

Apart from the larger herbivore information that is obtained form the annual aerial surveys, a monitoring system still needs to be developed that will reflect changes in smaller herbivores such as bushbuck and nyala. As invertebrates, especially termites, are a very important aspect of the herbivory component, this aspect should also be part of the monitoring programme.

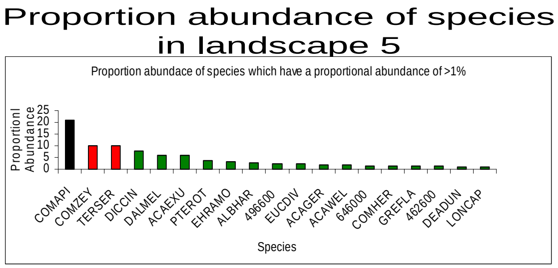
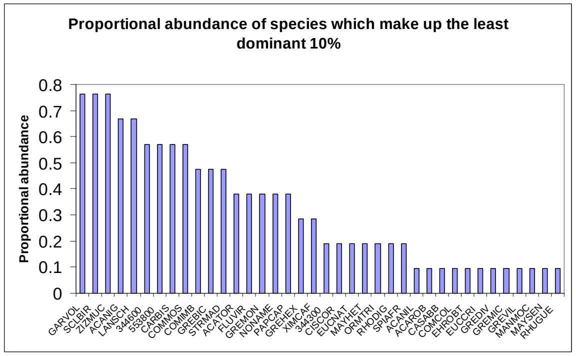
Future development

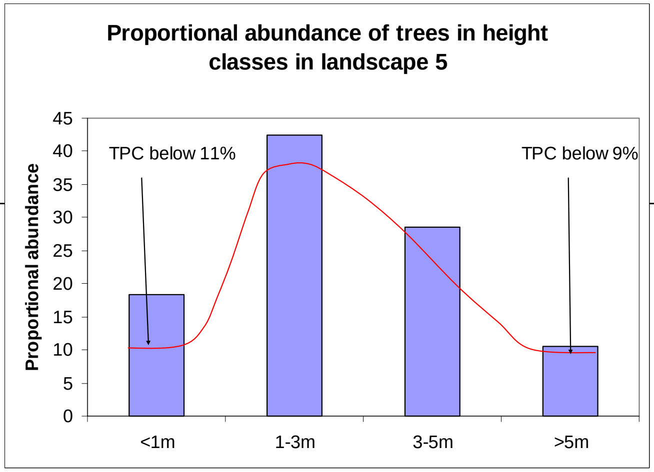
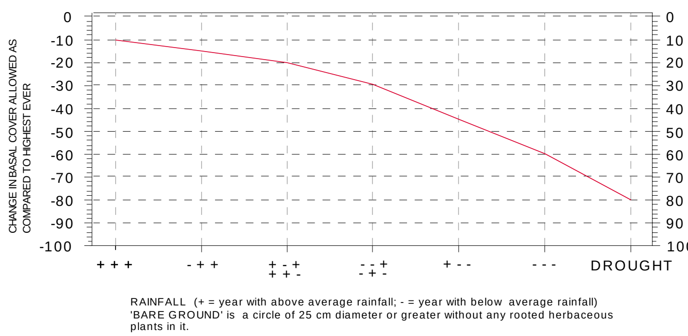
Vegetation TPCs are set as proportional rather than absolute changes as this provides a better measure of rate of change (with upper and lower limits) and provides a longer lead time to management action. However, absolute measures (e.g. trees /ha) are necessary as anchor points.

The herbivore TPCs will be adapted in future to track changes in the most important large herbivore groups these should represent bulk grazers, concentrate grazers, selective grazers, browsers, mixed feeders which should include both megaherbivores represented by elephant, and smaller herbivores, represented by impala and nyala. Insect herbivory requires attention, but we do not have any data to base TPCs on at this stage (We could start looking at this by research projects).

Vegetation TPCs

The spatial scale of the TPCs for compositional shifts is explicit in that they refer to the protected area as a whole or to a specific land unit (e.g. sensitive landscapes) within KNP. The bench mark studies used in defining these TPCs are Gertenbach 1978 & 1987, Van Rooyen 1978,Coetzee 1983, Venter 1990) where possible we would rather user theoretical thresholds but these still need to be developed

Element	**Scale**	**TPC exceeded**	
Woody vegetation Dominant species composition	*Landscape* *and where possible each terrain unit*	When the dominance ranking of the first or second ranked species descends to the third or lower position. A drop of less than 3% proportion abundance will not be considered a drop.	
Least dominant species component		For each landscape and where possible for each terrain unit a TPC will be reached when the least dominant 10% of species in a landscape as a group occupy less than ½ of the proportional abundance compared to the abundance of the least 10 recorded by Gertenbach. These species need not necessarily be the same species	

Diagnostic/differentiating species		For each landscape and where possible for each terrain unit within a landscape a TPC will be reached when such a species proportional abundance drops by more than 50% from that recorded by Gertenbach. This list of species will normally be restricted	
Woody structure/abundance		Per landscape: the proportional abundance of the <1m trees should not drop by more than 40% and the > 5m class should not have dropped by more than 10% of their proportions since the benchmark* or individuals in the >5m class have dropped by 1% for 3 consecutive surveys	
Herbaceous composition		At a landscape scale and where possible at a terrain unit scale for three consecutive years of above average rainfall the basal cover should not drop more than 10% but for a period of three years of below average rainfall this can drop by 60% and for a drought[1] this can drop by as much as 80% from the highest ever recorded.[2] This TPC will be developed further to look at relationships between production and rainfall, using remote sensing.	

[1]Drought= One year of 75% or less of long term mean annual rainfall

[2] This takes increase in bare ground into account as the inverse of cover is bare ground so as cover decreases bare ground increases

Herbivore TPCs

Element	Theoretical threshold/Benchmark	Scale	TPC exceeded	Species
Counter trend TPC *:*	Mills et al. 1993)	Entire KNP	When there are three monotonic drops of the estimated count (ignoring the confidence intervals) of more than 10% overall in wildebeest population numbers in a dry cycle (3 years below average) Three monotonic drops of more than 10% in kudu and waterbuck population numbers in a wet cycle (3 years of above average rainfall).	Wildebeest, Kudu & waterbuck
Dominance switch in large herbivores	Counts during the aerial census, between 1980 and 1993.	Landtypes/ landscapes	When the dominance ranking of the first or second ranked species descends to the third or lower position. A drop of less than 5% proportional abundance will not be considered a drop.	Species adequately covered by aerial census: impala, giraffe, wildebeest, kudu, white rhino, elephant, waterbuck, warthog and zebra.
Loss of the least dominant species component	Counts during the aerial census - abundance of the least 3 recorded between 1980 and 1993.	Landtypes/ landscapes	When the 3 least dominant as a group occupy less than ½ of the proportional abundance in the benchmark For each species lost if the species has also been lost from more than 50% of	This will include all less common species including sable, tsessebe, roan, reedbuck and black rhino

			the landscapes.	
Range contraction or expansion	Consistent occupancy (7/13 years) of the census strip widths in all years from 1980 to 1993	KNP wide	With a 25% reduction/increase in no of 1 km^2 pixels which contain that species, based on 1km sections of the current strip widths.	Species adequately covered by aerial census: impala, giraffe, wildebeest, kudu, white rhino, elephant, waterbuck, warthog and zebra.

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