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Research article

Expert-derived monitoring thresholds for impacts of megaherbivores on vegetation cover in a protected area

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ABSTRACT

Monitoring is meant to inform conservation authorities, yet managers often don't know when to respond to monitoring results. One of the reasons is that management often lacks consensus on monitoring thresholds for intervention. This results in aimless monitoring without a clear directive on when monitoring indicates a trajectory towards an unacceptable state or impending change, which possibly necessitates intervention. Although experts rarely provide simple, measureable and quantifiable monitoring thresholds as required by management, they are often more comfortable expressing opinions on whether a specific area is desirable or not. This allows thresholds to be *reverse engineered*: by getting experts to identify sites as desirable and undesirable, field variables can subsequently be measured to derive the boundary between subjectively identified desirable and undesirable states. Such a boundary provides a defendable point for management to assess and consider intervention. Here we describe the identification of monitoring thresholds by defining the limits of desirable canopy cover, derived from expert stakeholder preferences, in the Sundays Spekboom Thicket vegetation of the Addo Elephant National Park, South Africa. The park has experienced variable utilization intensity by large herbivores, especially elephant. For years managers have grappled with the question of what percentage shrub canopy cover is desirable as a management target, but science has failed to provide this. Using experts to assess pre-selected sites as desirable or undesirable across a range of canopy covers, we showed that a canopy cover of ~65% (±15%) would be desirable for expert stakeholders. We then used satellite imagery to map canopy cover, providing managers for the first time with a large-scale map of canopy cover, indicating desirability status. This approach was useful for facilitating joint-decision making between conservation agencies and stakeholders on tangible indicators of achieving goals, and may be useful in fostering relationships, trust, mutual understanding and transparency, characteristics critical for managing complex socio-ecological systems.

1. Introduction

Despite the paucity of appropriate data, conservation management decisions must be made (Kuhnert et al., 2010). To deal with the ecological uncertainty, learning-by-doing approaches such as adaptive management are particularly attractive because they promise to improve long-term management outcomes by learning (through appropriate monitoring or research) in the short-term (Holling, 2001). While there is extensive support for the theoretical merits of adaptive management, there are few examples where the approach has been implemented successfully (e.g. Allen and Gunderson, 2011; Keith et al., 2011). A number of factors are blamed for this failure, including an inability to identify clear and quantifiable management objectives, an unwillingness to invest in costly and risky long-term experiments, and failure to evaluate the performance of management interventions (Allen and Curtis, 2005;

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Allen and Gunderson, 2011). Successful adaptive management is also dependent on the implementation of a strategic (adaptive) monitoring programme for learning. Unfortunately, many monitoring programmes are ineffective or fail completely owing to a lack of focus or poor planning (Walters, 1997; Possingham et al., 2001; Lindenmayer and Likens, 2009; Keith et al., 2011). More specifically, and probably more relevant to decision-making for conservation management, is that these programmes often lack clear monitoring thresholds, or assessment points (Bennetts et al., 2007). The identification of thresholds requires management and scientists to assess the situation and consider if intervention may be needed to prevent undesirable changes (Possingham et al., 2001; Biggs et al., 2011). Without thresholds, monitoring may be aimless, leaving management without clear directives for intervention.

Monitoring thresholds can be defined in various ways, but they are largely determined by predefined management objectives and available information. In some cases ecological thresholds, where a system rapidly shifts from one (desirable) state to another (undesirable) state, may be used to define monitoring thresholds. In such cases, monitoring thresholds should be more conservative than ecological thresholds, to allow adequate time for intervention before exceeding the threshold. However, identifying ecological thresholds and associated monitoring thresholds may be exceptionally difficult in practice (Hughes et al., 2013). An alternative method of defining monitoring thresholds, especially when ecological thresholds are not known (as is mostly the case), is to define the boundary between subjectively defined desirable and undesirable states. This boundary does not represent a verifiable ecological threshold that leads to state changes, but rather represents a value (or range of values) of a particular variable along a desirable-undesirable continuum. Expert opinion is one way of defining desirable and undesirable states.

Forty years of research in the subtropical succulent thicket (hereafter thicket) of the Addo Elephant National Park (AENP), South Africa, has demonstrated the negative consequences for thicket plant biodiversity of maintaining high levels of utilization by megaherbivores (especially African elephant *Loxodonta africana*) (e.g. Penzhorn et al., 1974; Landman et al., 2014). Impacts on the canopy shrub community, which shapes both the structural and functional complexity of the landscape, are particularly dramatic, and significant declines in plant species richness, density and biomass have been recorded (Penzhorn et al., 1974; Moolman and Cowling, 1994; Lombard et al., 2001; Landman et al., 2014). Importantly, fence-line contrasts and long-term monitoring results reveal that thicket is vulnerable to transformation following prolonged utilization, which causes the system to change to a grassy or dwarf (karroid) shrubland (Lechmere-Oertel et al., 2005; Landman et al., 2014). Despite extensive monitoring, no clear monitoring thresholds have been defined that will prompt management to critically assess and respond to unacceptable change. One way to overcome this impasse is to use expert opinion, integrated with ecological data, to quantify monitoring thresholds, thus estimating the subjective boundary between desirable and undesirable states. We adopt such an approach for vegetation canopy cover in the AENP.

Our aims were to (1) determine if common monitoring thresholds can be derived between different expert groups, including scientists, conservation managers and farmers, and (2) assess whether satellite remote-sensing can be used to map the monitoring thresholds across larger scales to inform management decisions. While experts rarely provide simple, measureable and quantifiable monitoring thresholds for managers, they are often more comfortable in expressing their opinion on whether a specific patch of habitat is in a desirable or undesirable state. In this study we took experts to a range of sites to rate on a predefined scale the desirability of thicket canopy cover at each site. We also physically measured canopy cover at the same plots. Having both the experts' desirability rating and the measured canopy cover for each site, our approach allowed monitoring thresholds to be reverse engineered by determining what value of canopy cover can be used to distinguish between sites which were deemed desirable and undesirable by experts. These outcomes provide a quantifiable and defendable desirability envelope that management can use when interpreting canopy cover monitoring data.

2. Methods

2.1. Study site

AENP (33°31′S, 25°45′E) is situated in the Eastern Cape, South Africa. The park comprises several fenced sections, with the majority of the elephant population confined to our study site (i.e. the Main Camp/Colchester section, covering approximately 260 km^2 as of 2010). AENP was originally fenced in 1954 to enclose the remaining elephant of the region and incrementally expanded to support the growing population, while simultaneously reducing impacts on biodiversity. Several large herbivore exclosures were established to protect plant species particularly vulnerable to herbivory, but also for research purposes. These exclosures were designed to exclude elephant, black rhinoceros *Diceros bicornis* and buffalo *Syncerus caffer*, but allow free access for other herbivores.

The region is semi-arid: annual rainfall is about 400 mm, and heavy falls as well as prolonged dry spells may occur at any time of the year. Soils are derived from Kirkwood Formation (Cretaceous) shales and are deep and nutrient-rich. The prevalent vegetation type is Sundays Spekboom Thicket, a form of succulent thicket associated with the Albany Thicket Biome (Vlok et al., 2003). The Albany Thicket Biome comprises the southwestern portion of the Maputaland-Pondoland-Albany hotspot (Steenkamp et al., 2004) and is renowned for its high diversity of endemic succulents and geophytes (Vlok et al., 2003), many of which are threatened by the impacts of both domestic and indigenous herbivores (Moolman and Cowling, 1994; Lombard et al., 2001; Kerley and Landman, 2006). The AENP provides an important site for the conservation of thicket plant diversity; of the park's 581 species (as of its area in 1997), 72 (12.4%) are categorized as endemic and/or threatened, and 187 (32.2%) are not conserved in any other protected area in the Albany Thicket Biome (Johnson et al., 1999).

Sundays Spekboom Thicket comprises a 2–4 m high, dense, evergreen, spinescent and vine-rich shrubland, containing many succulents and geophytes. The tree-succulent *Portulacaria afra* (spekboom) is locally dominant and occurs in a matrix of spinescent shrubs and low trees, while the understory hosts dwarf succulents, forbs and geophytes. Grasses may be seasonally abundant in secondary grasslands and where intensive herbivory has removed the canopy shrubs (Landman et al., 2014).

2.2. Study design

We collected data at 15 sites comprising plots of 50 m × 50 m, located in the Main Camp section and restricted to Sundays Spekboom Thicket (Fig. 1). Plots were selected to cover the full range of available thicket shrub canopy cover, from an intensively utilized plot close to water where the canopy shrubs are nearly completely removed, to a lightly utilized plot in a large herbivore exclosure where shrub cover mostly exceeds 80%.

For each plot we (1) elicited opinion from experts using a questionnaire for assessing the desirability of vegetation status, (2) measured shrub canopy cover along line-transects and enumerated