SHORT COMMUNICATION: The impact of inter-observer variability on the accuracy, precision and utility of a commonly-used grassland condition index

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Abstract

Inter-observer variability in ecological surveying can reduce the robustness and reliability of measures used to inform habitat management. Grassland management is important across southern Africa. The Veld Condition Index (VCI) is a technique that combines field data on the relative abundance of grasses identified during a standardised survey with knowledge of how different grass species respond to grazing. This allows calculation of an Ecological Condition Index (ECI) for a particular site. The ECI value is related to threshold values to indicate grazing pressure. Here, for the first time, the effects of inter-observer variation in trained surveyors on condition assessment and resultant management recommendations are examined. There was substantial and statistically significant inter-observer variation in ECI values, driven primarily by differences in the number of times an observer identified grasses within the sample transect as being one of the species listed in the “Decreaser” category of the standardised protocol (i.e. species that decrease with grazing). Variation was random with respect to observers rather than being due to systematic (and thus predicable and potentially correctable) differences between observers. In 44% of sites, inter-observer variation resulted in important differences in assessment of grassland condition because the assessment spanned outcome threshold categories. In such cases, this could result in unnecessary or detrimental management being recommended by some observers including inappropriate burning, needlessly translocating or culling herbivores, or failing to align herbivore populations to the carrying capacity with negative effects on both grazers and veld. We recommend that a cautious approach be taken in using VCI/ECI to inform management and that identification training be focused on species in the Decreaser ecological category that drive inter-individual variation in overall ECI.

Highlights

- Inter-observer variability (IOV) is a major problem in ecological indicator systems
- Substantial IOV occurred in grassland condition assessment using Veld Condition Index
- In 44% of sites IOV caused potential deleterious management recommendations
- We recommend focused training to overcome problems caused by IOV

1. Introduction

Ecological surveying and monitoring are the foundations of an evidence-based approach to habitat management (Lindenmayer and Likens, 2010; Goodenough and Hart, 2017). Initial classification of habitat type can be achieved through broad surveys (for example, Phase One Habitat Surveying: Joint Nature Conservation Committee, 2010) but assessment of habitat-specific condition is often necessary to inform effective management and this typically involves using an ecological indicator system (e.g. Kelly et al., 2009; Kolada et al., 2014).

To be useful, any ecological indicator must be robust. Inter-observer variation, whereby there is disagreement in the data collected by different surveyors, is a common source of error even in relatively simple ecological contexts such as biometric-based estimates of avian and insect condition (Goodenough et al., 2010, 2012), habitat mapping (Cherrill and McClean, 1999), and estimation of vegetation cover or community assemblage (Novellie and Strydom, 1987; Hearn et al., 2011). However, although the topic of inter-observer variation has been studied in a range of systems, there is very limited research that specifically assesses the implications for professional practice and management decisions (Kolada et al., 2014; Cherrill, 2015). This is despite the fact that any differences in data that arise from variation between observers, for example due to inconsistencies in technique or identification skills, could result in drastically different site assessment conclusions or management recommendations, as found previously for assessment of herbivore damage to inform potential culling (MacDonald, 2010).

Grasslands in southern Africa (south of the Zambezi and Kuene rivers, including Zimbabwe, Botswana, Namibia, South Africa, Eswatini and Lesotho (van Oudtshoorn, 2018)) have considerable ecological importance and are often actively managed to increase their productivity and biodiversity (Carbutt et al., 2011). The Veld Condition Index (VCI) is a well-established monitoring approach through which grassland condition can be determined (e.g. Tainton et al., 1980; Vorster, 1982; Hurt and Bosch, 1991). Although there are several specific methods, VCI usually involves identification of grasses along a 100 m or 200 m transect. Each species is assigned to an ecological group based on its ecological status as per published sources (e.g. van Oudtshoorn, 2018) and has an associated multiplier (Table 1). An overall Ecological Condition Index (ECI) is calculated by summing the number of sampled grasses in each ecological group and then multiplying the total by the corresponding multiplier. The final ECI value can be compared to a threshold that indicates whether the condition of the sampled grassland is poor (<400), moderate (400-599) or good (600+) (Tainton et al., 1980; Heard et al., 1986) or with reference to a benchmark on the site of interest when ECI is expressed as a percentage of that benchmark. Condition assessments are used to inform potential management interventions including direct grassland management (rotational burning or mowing), moving herbivores from over-utilised areas to under-utilised areas by creation of new waterholes and/or closure of existing waterholes, or reducing herbivore numbers by translocation or culling (van Rooyen and Bothma, 2016).

Table 1: Grasses are assigned an ecological status category depending on their response to grazing. The overall Ecological Condition Index (ECI) is determined by multiplying the percentage of species in each category from a transect (if the transect is 100 m in length with a sample every metre, as here, the percentage and number of samples in each status category are synonymous) by the multiplier for that category and summing across all four categories (categories from Camp and Hardy, 1999 and Van Oudtshoorn, 2018; multipliers following Tainton et al., 1980). ECI can range from a theoretical minimum of 100 (all grasses in Increaser III category) to a theoretical maximum of 1,000 (all grasses in Decreaser category). A similar approach with five ecological classes with grazing value multipliers of 10, 7, 5, 4 and 1 is also in use (see van Rooyen and Bothma, 2016).

Ecological Status Category	Description	Multiplier
Decreaser	Palatable climax species with high productivity that abundant in good veld; decrease when overgrazed	10
Increaser I	Moderately palatable climax species; increase in underutilised veld	7
Increaser II	Unpalatable pioneer and sub-climax species increase in overgrazed veld	4
Increaser III	Unpalatable climax species; increase in overgrazed veld	1

The VCI and ECI methods are widely used across southern Africa (e.g. Bothma et al. 2004; Ngwenya, 2012; Trollope et al. 2014; van Rooyen and Bothma, 2016; Harmse and Gerber 2018), largely because they constitute a conceptually straightforward and rapid method of assessing the need for, and effectiveness of, grassland management (Ngwenya, 2012). There has previously been some consideration of the appropriateness of VCI/ECI as an ecological indicator. Cumming (2011) showed that ECI scores are not always closely correlated with herbivore biomass or numbers, as would be expected if the method is to be useful predictively to assess stocking levels as per the theoretical modelling of van Hoven (2002). This is likely because the relationship between veld condition and herbivores is triangular rather than linear or curvilinear (Cumming, 2011). This is possibly due to non-appropriate transference to wildlife management of a system developed originally to assess condition of cattle grazing areas without due regard for the different links between ecological succession of grasses and grazing preferences in the different systems (Westoby et al. 1989; Vetter, 2005). In terms of methodological considerations, however, seemingly the only published studies, are those of du Toit (2000) who challenged the subjective nature of the disjunct scoring system and Hart et al (2020) on optimising the number of datapoints on which ECI assessments are based.

To date, there have been no empirical assessments of whether trained grassland surveyors of similar ability exhibit variation when using the VCI/ECI method to survey the same area of veld, and, if so, whether such inter-observer variation would be substantial enough for sites to be placed in different condition assessment categories and thus potentially affect management recommendations. This study is thus the first to examine the effect of inter-observer variability in ECIs for managed grassland anywhere in Southern Africa, consider the influence of such variation on management recommendations, and offers suggestions how this widely-used approach could be improved to become more robust. Moreover, because this is the first time inter-observer variation has been considered for an ecological condition indicator based on terrestrial vegetation, the findings of this study have widespread implications within ecological indicator science.

2. Materials and methods

This study was carried out in autumn 2019 at a private reserve in Northwest Province, South Africa. The site is 4,700 ha and is managed through rotational block burns on a five-year cycle with ~20% of the reserve burned every year. The reserve is a mixture of sweet veld (high fertility soil; low altitude; vegetation sensitive to overgrazing) and sour veld (low fertility soil; higher altitude; vegetation tolerant of overgrazing) (Tainton, 1999; van Oudtshoorn, 2018) that should be suitable for grazing for eight to ten months of the year (van Rooyen and Bothma, 2016). It supports ~1,500 individuals from 49 large mammal species including white rhinoceros (*Ceratotherium simum*), blue wildebeest (*Connochaetes taurinus*), zebra (*Equus quagga*) and giraffe (*Giraffa camelopardalis*). Animals can roam freely across the reserve with grazing pressure and burn management requirements being monitored regularly through use of VCI.

Study sites were selected using systematic random sampling across the reserve in accordance with Foran et al. (1978) and Trollope et al. (1989) with each site being predominately grassland of consistent sward height. At each of the 36 study sites seven observers undertook individual VCIs by walking a 100 m transect with a survey cane, identifying the single grass species closest to the cane after each 1 m step ("spike-point sampling" (Ngwenya, 2012)). This was a slight adjustment to the standard step-point method using foot placement (Mentis, 1981; van Rooyen and Bothma, 2016) to avoid potential biases caused by preferential foot placement in areas of bare ground or short vegetation. To ensure that seven individual surveys at each site were fully independent, observers did not confer. The ecological status (Table 1) of each identified grass species was ascertained using van Oudtshoorn (2018) and absolute ECI (rather than ECI as a percentage relative to a benchmark) was calculated on a per-transect basis. This gave seven independent ECI estimates, each based on 100 grass samples, for each site thereby giving 7*36 = 252 ECI estimates based on 25,200 grass identifications in total.

For each site, mean ECI was calculated using the seven independent ECI estimates. The maximum and minimum ECI estimates at each site were also identified. Site condition was determined from the mean ECI value as per standard convention (<400 = poor; 400-599 = moderate; 600+ = good: Tainton et al., 1980). Sites were then divided into those for which all seven condition estimates were in the same category as the mean whereby resultant management recommendations relating to grazing or burning would likely be the same (*consistent sites*), and those sites where at least one condition estimate differed from the mean and where resultant management recommendations could differ (*disputed sites*).

Inter-observer variation was calculated for each site using the coefficient of variation (CV) expressed as a percentage (CV = (standard deviation / mean) * 100). This approach has been used in previous studies of inter-observer variability of biological estimates (e.g. Pankakoski et al. 1987; Goodenough et al. 2010, 2012) and in a study on the precision of repeated VCI data between different seasons (Mentis et al., 1980). The advantage of using CV rather than standard deviation is that CV decouples variability from the underpinning data and thus allows variability to be directly compared even where, as here, mean values differ substantially between sites.

To assess whether inter-observer variability was related to grassland condition, Spearman's rank correlation was used to examine the relationship between inter-observer variation (CV values) and mean ECI values for each site. The same approach was used to test of a possible relationship between the complexity of the vegetation community (number of species) and inter-observer CV values. To test whether some observers were statistically more variable to others, a one-sample Kolmogorov-Smirnov test was performed against a uniform distribution. To analyse whether inter-observer variation in ECI was significant, a repeated measures ANOVA was undertaken as per Palmeirim (1998) but using the Greenhouse-Geisser method to compensate for sphericity. In all cases, individual observer was entered as a 7-level factor with ECI entered as the dependent variable. This approach was also used to assess inter-observer variability in the number of grasses assigned to the Decreaser, Increaser I, Increaser II and Increaser III categories by each observer at each site to establish what was driving variability in the overall ECI value. Since the number of grasses in each category is not only non-independent but actually mutually interdependent (i.e. if a species is in one category it cannot be in any other category (Mentis et al., 1980)), Bonferroni corrections were applied. All analyses were undertaken in SPSS v24.

3. Results

Within the complete dataset of 252 VCIs there were 45 grass species represented. These were divided thus: Decreaser = 7 species; Increaser I = 9 species; Increaser II = 26 species; and Increaser III = 3 species. The most common species were: broad curly leaf (*Eragrostis rigidior*) (12.2%), common russet (*Loudetia simplex*) (11.7%), finger grass (*Digitaria eriantha*) (8.0%), wool grass (*Anthephora pubescens*) (5.7%) herringbone (*Pogonarthria squarrosa*) (5.6%), tassle three-awn (*Aristia congesta*) (4.8%), and wire grass (*Elionurus muticus*) (4.5%). Overall 22% of datapoints were in the Decreaser category, 19% were Increaser I, 54% were Increaser II and 5% were Increaser III.

Site-specific ECIs were calculated using the mean of all seven ECIs at that site and ranged from 439 to 714. This resulted in the condition of 23 sites being classified as "moderate" and 13 sites as "good". There was considerable variability in ECI between observers (Figure 1).

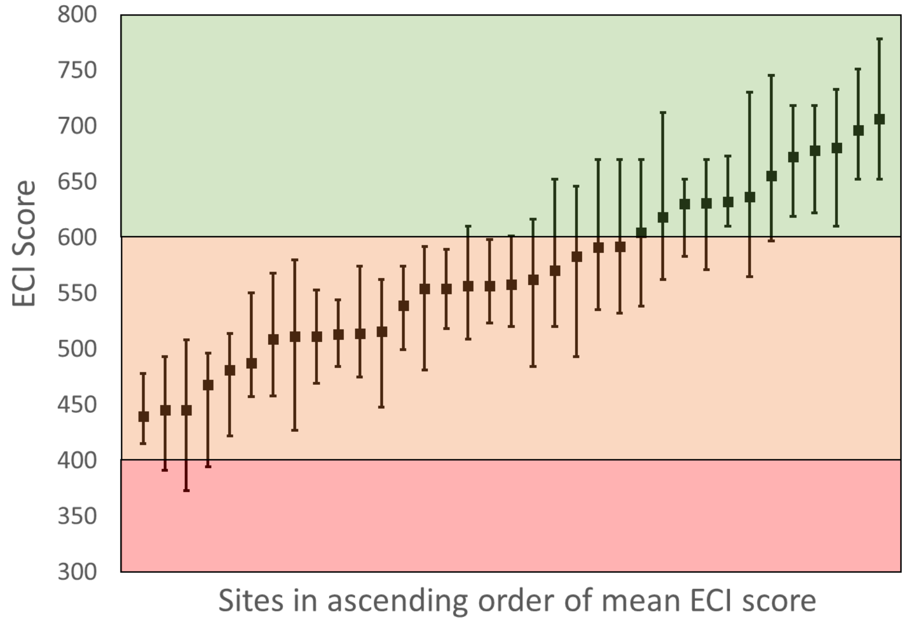

Figure 1: ECI scores for 36 sites surveyed independently by 7 observers where the datapoint shows the site-specific mean of all ECI estimates for that site and the bars the range. Sites are arranged in order of mean ECI score. The coloured zones indicate: red = poor condition (ECI <400), amber = moderate condition (ECI 400-599), green = good condition (ECI 600+).

The mean difference between the site-specific minimum ECI and the site-specific maximum ECI (i.e. the range indicated by the bars on Figure 1) was 108.33 (± 28.93 SD). The magnitude of inter-observer variation itself varied between sites (inter-observer CV values for different sites ranged from 4.09% to 10.98%; mean = 6.92%) but there was no significant correlation between mean ECI mean and inter-observer CV (Spearman's rank: r_s = -0.209, n = 36, p = 0.222; Figure 2). This suggests that the actual ecological condition of a site, as assessed through vegetation responses to grazing pressure, did not influence the accuracy with which that site can be assessed. However, there was a significant positive correlation between the number of species in the grass community of a site and inter-observer variation in assessing the ECI of that site (Spearman's rank r_s = 0.394, n = 36, p = 0.017; Figure 3). This suggests that sites with more complex vegetation communities were more prone to increased effects of inter-observer variation amongst surveyors.

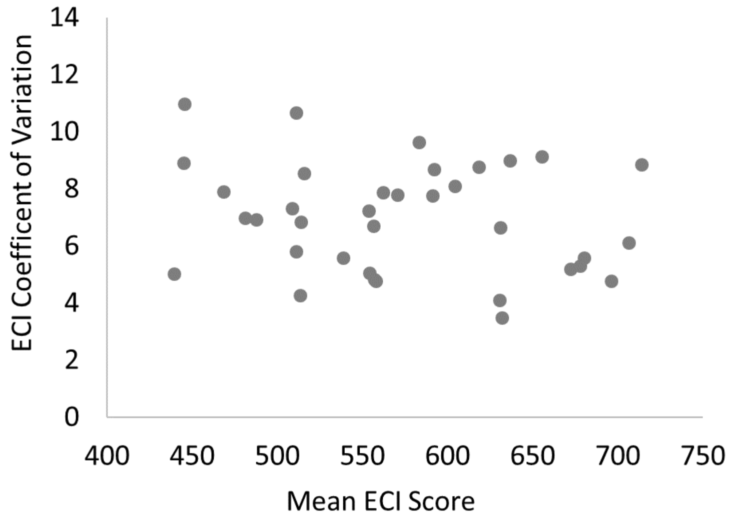

Figure 2: Lack of correlation between mean ECI score for 36 sites surveyed by seven observers and the site-specific coefficient of variation in ECI scores between those observers (.

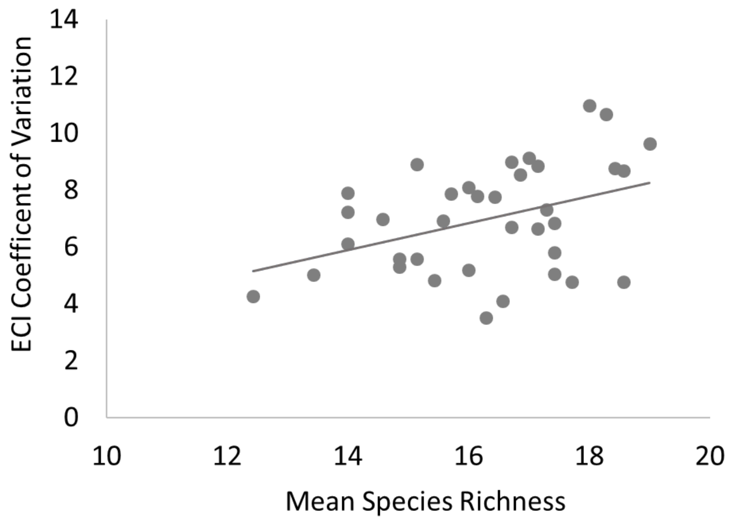

Figure 3: Significant positive correlation between the number of species in the vegetation community of 36 sites and the coefficient of variation of ECI scores between observers for that site.

As suggested by the high range between minimum and maximum ECIs for most sites (Figure 1), inter-observer variability in ECI was statistically significant (repeated measures ANOVA f= 5.997, df = 4.304, p<0.001). However, variation was random with respect to observers rather than being due to systematic (and thus predictable) differences between individuals (as might occur, for example, because of a specific observer routinely ascribing common grasses to an incorrect ecological status category). The consistency in observer-specific CV values is shown in Table 2. There was no significant difference in the CV values of the seven observers relative to a uniform distribution (Kolmogorov-Smirnov test z = 0.756, n = 7, p = 0.617).

Table 2: Mean CV values in ECI site assessments for each of the seven observers (each observer assessing the same 36 sites)

Observer	1	2	3	4	5	6	7	Mean
CV values (%)	15.9	15.8	14.6	14.9	13.8	14.1	14.0	14.7

Since ECI was derived from the percentage of grasses in each ecological status category (synonymous with number in this dataset as total sample size for each individual at each site was 100), it was important to assess what was driving this variation by assessing inter-observer variation in the underpinning data. The number of grasses in the Decreaser and Increaser III categories was significantly different between observers, whereas the number of grasses in the Increaser I and Increaser II categories did not differ significantly (Table 3).

Table 3: Repeated measures ANOVAs to assess inter-observer variation in VCI field data underpinning ECI calculation (see Table 1 for definition of variables). The Greenhouse-Geisser method has been used to reduce degrees of freedom to compensate for sphericity and p values were Bonferroni-corrected by multiplying by four to account for lack of independence in the number of samples in each ecological status category within in each VCI sample.

Variable	F	DF	Bonferroni-corrected P
Number of Decreasers	4.479	4.163	0.008
Number of Increaser I	2.844	3.943	0.108
Number of Increaser II	2.140	4.784	0.264
Number of Increaser III	11.162	3.570	<0.001

The individual ECI scores from each of the seven observers resulted in the same assessment of condition in 20 of the 36 sites (agreed sites; 56%). Of the 16 sites where variation in ECI spanned condition categories, such that assessment of condition would differ between the observers (disputed sites; 44%), 13 were a mixture of moderate and good (36% of all sites) and 3 were a mixture of poor and moderate (8% of all sites). In total, there were 29 site-specific condition assessments that differed from the mean condition assessment, as determined by the mean ECI value, for that site. Since there were 112 independent condition assessments across the 16 disputed sites (seven ECI values per site) this meant that there was a condition assessment mismatch in 25.9% of cases in disputed sites.

4. Discussion

Substantial and significant inter-observer variation was found in ECI across sites in this study. The presence of inter-observer variation is not surprising given previous studies highlighting this issue for vegetation data (e.g. Cherrill and McClean, 1999; Hearn et al., 2011 Cherrill, 2015). However, what makes this finding important is the substantial applied implications of this inter-observer variation on management actions. We found that inter-observer variation resulted in differences in assessed condition between observers at just under half (44%) of sites because the outcome (condition category) differed. This is similar in magnitude to the 40% risk of lakes assessed using the Ecological State Macrophyte Index being placed in the incorrect condition category due to inter-observer variation (Kolada et al., 2014), but this is the first time this problem has been demonstrated for an ecological condition indicator based on terrestrial vegetation. As ECI is widely used to inform management across the African continent, this has widespread implications.

In our study, the clear implication is that inter-observer differences in surveying could, through the calculation of ECI and subsequent condition assessments, lead to incorrect or unnecessary management. This could include burning when it is not necessary (which could have deleterious effects on other taxa especially field-layer invertebrates), translocating or culling animals to reduce stocking density unnecessarily, or failing to burn or manage herbivore populations when carrying capacity has actually been breached thereby causing severe overgrazing and soil erosion as well as potential morbidity or mortality in herbivores (Tainton et al., 1980; Ngwenya, 2012). Grazing pressure and its influence on herbivore carrying capacity and stocking densities is the primary reason for using VCI/ECI to inform grassland management (Foran et al., 1978; Vorster, 1982; Trollope et al., 1989; van Rooyen and Bothma, 2016).

We have shown that differences between sites in ECI were driven by significant variation in the number of datapoints in the Decreaser and Increaser III ecological status categories; grasses in these categories are those species most affected by, and indicative of, overgrazing (van Oudtshoorn, 2018). This suggests that surveyors using VCI should pay particular attention to identifying species in these categories correctly. However, as recognised by Mentis et al. (1980), the lower abundance of Increaser III grasses in most grasslands (5% in this study) can lead to inflated CV values and overestimate of the importance of Increaser III grasses in driving overall variation in ECI. We thus recommend that surveyor training should focus upon accurate identification of Decreaser grasses since increasing identification accuracy for these species would reduce risk of inter-observer variation at source, leading to more robust ECIs and subsequently more robust condition assessments. This is akin to the key species methods developed for Kruger (Trollope et al., 1989) but based on ecological category rather than a subsample of species across categories.

We have also shown that statistically higher rates of inter-observer variation occur at sites where the vegetation community itself is more complex. We thus recommend that sites with higher levels of species richness are surveyed especially carefully, either by highly-experienced field surveyors or by multiple surveyors with an average assessment being calculated and used to determine appropriate management interventions.

5. Conclusion

Overall, this study reveals that although VCI is a conceptually straightforward and rapid method for assessing grassland (Ngwenya, 2012), it is sensitive to inter-observer variation. In terms of immediate implications for practice, we recommend that specific care is taken: (1) to correctly identify and classify grasses in the Decreaser ecological group; and (2) that ecologically complex sites are surveyed especially carefully given the link between grass species richness and inter-observer variability. More generally, the issues raised here on inter-observer variation are in addition to concerns raised by other researchers on the appropriateness of what is essentially a repurposed survey method for land used by cattle (Westoby et al. 1989; Vetter, 2005), especially given the link of a direct link with grazing intensity in some areas (Cumming, 2011). Although it could be argued that such inter-observer variation would only be problematic at reserves where multiple surveyors are involved in assessing condition (where assessment would be inherently linked to surveyor), we contend that the variation in results between trained field surveyors is indicative of a more fundamental lack of robustness in the approach and that, as a consequence, there is considerable potential for mismanagement if management decisions are based solely on VCI.

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