The Verification of Wilderness Area Boundaries as Part of a Buffer Zone Demarcation Process: A Case Study from the uKhahlamba Drakensberg Park World Heritage Site

Sonja C. Krüger, Ian A. Rusworth, and Kirsten Oliver

Abstract—Wilderness areas are by definition free from the sights and sounds of modern man. The boundaries of wilderness areas have traditionally been defined based on the management authorities' perceptions of which areas have wilderness quality. Experience shows that many areas classified as wilderness do not actually have wilderness qualities and do not provide a true wilderness experience, while other areas not classified as wilderness may indeed provide a wilderness experience. In addition, there are many cases where areas that previously provided a wilderness experience no longer qualify as wilderness as a result of developments that have taken place outside the protected area.

This paper describes the methods employed to re-define the boundaries of the wilderness areas of the uKhahlamba Drakensberg Park World Heritage Site based on visual impacts of existing developments, using a Digital Terrain Model and Viewshed Analysis in a Geographic Information System. This action is required prior to embarking on a process to delineate a buffer to protect the pristine wilderness of the Park. A field verification using a random sample of points was used to confirm the revised boundaries, and an error matrix was compiled. The analysis indicates that 19,701 ha classified as pristine wilderness no longer have wilderness qualities, and, likewise, 42,492 ha not classified as wilderness could qualify as pristine wilderness. The zoned pristine wilderness area of the Park is 34,026 ha, but a pristine wilderness experience can be had in 56,817 ha of the Park.

The focus of the buffer zone demarcation is in the pristine wilderness zone and the management team will not compromise on the true wilderness qualities of this zone. However, the results of the error matrix were not satisfactory for the pristine wilderness category. We recommend that the Viewshed Analysis is re-run at a higher resolution to identify 'true' pristine wilderness. This process will ensure that the realignment of wilderness zone boundaries is accurate. A process can then be implemented to identify areas outside the protected area that need to remain in their current undeveloped state to buffer the pristine wilderness areas and prevent any further erosion of the size of these areas.

Introduction

The uKhahlamba Drakensberg Park (hereafter referred to as the Park) was designated by UNESCO as a World Heritage Site (WHS) in November 2000 and gazetted as a WHS on July 11, 2008. The Park is managed by Ezemvelo KwaZulu-Natal (KZN) Wildlife, a provincial conservation organization.

Since being gazetted, a number of planning tools required to manage the Park have been developed. These include an Integrated Management Plan (Ezemvelo KZN Wildlife 2005a) incorporating a wilderness area management plan, a concept development plan, and a business plan. These plans have focused principally on areas within the designated protected area.

Given concerns that development and land use changes outside protected areas can have negative impacts on the purpose and values of protected areas, South African legislation (National Environmental Management: Protected Areas Act No. 57 of 2003 and World Heritage Convention Act No. 49 of 1999) makes provision for the establishment of buffer zones outside protected areas with the purpose of protecting the values for which these areas were gazetted. A process to establish an appropriate buffer zone was initiated in 2006. The approach of Wild and Mutebi (1996) was adopted where the buffer zone is an area that is managed with the aim of enhancing the positive and reducing the negative impacts of conservation on neighboring communities and of neighboring communities on conservation.

The primary purpose of the buffer zone is to protect the purpose and values of the protected area. The core values of the Park include the value of the natural heritage, cultural heritage, water production, eco-cultural tourism, and wilderness (Ezemvelo KZN Wildlife 2005a). The value of

Sonja C. Krüger and Ian A. Rusworth are ecologists with Ezemvelo KwaZulu-Natal Wildlife, PO Box 13053, Cascades, 3202, South Africa.

Kirsten Oliver is a GIS Specialist with the Endangered Wildlife Trust, Private Bag X11, Parkview, 2122, South Africa. FAX: +27(0)332391515, E-mail: skrueger@kznwildlife.com.

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wilderness is reflected in the purpose of the protected area as providing access for the public to the area and its resources, including the spiritual values provided by wilderness areas. In order to protect and enhance the wilderness experience of park users, the buffer objective relating to wilderness was to safeguard wilderness values from additional negative impacts. The secondary objective was to mitigate existing negative impacts on wilderness users.

Prior to embarking on a process to delineate a buffer zone to protect the Park's wilderness values and qualities, the current boundaries of the Park's wilderness areas needed to be validated. The management team recognized that land use changes since the proclamation of the Park's wilderness areas in 1973 and the zonation of the Park in 2006 may have significantly eroded the qualities and values of the Park's wilderness areas. This paper focuses on the methods used to re-define the boundaries of the wilderness areas of the Park based on the visual impacts of existing developments. This verification process will improve the accuracy of the Park's zonation boundaries, which will ensure that the buffer zone process conserves opportunities for people to experience solitude and spiritual renewal in pristine wilderness areas of the Park.

Study Area

The uKhahlamba Drakensberg Park is a 242,813 ha protected area situated in the KwaZulu-Natal Province of the Republic of South Africa and is part of the Drakensberg mountain range in south-eastern Africa (fig. 1). The Park's western boundary lies on the international boundary with the Kingdom of Lesotho. The Park is a national and international asset due to its unique natural and cultural value and, as such, it has been listed as a World Heritage Site of dual significance.

The Park has a diverse range of ecological niches with rich biodiversity and large numbers of endemic species. In addition, it is home to thousands of rock art paintings, a product of the San's long historical relationship with this mountain environment (Mazel 1989). The Park also plays a key role in the economy of KwaZulu-Natal and South Africa, through the production of high quality water from its dense network of wetlands, and as an anchor for regional tourism development (Ezemvelo KZN Wildlife 2005a).

The Park is crescent-shaped with an approximate total length of 158 km and width of 28 km at its widest point. The height above sea level extends from approximately 1,200 m to 3,408 m. The mean annual temperature of the Drakensberg is about 16 degrees Celsius and annual precipitation varies between about 1,000 mm in the foothills to 1,800 mm at the escarpment (Tyson and others 1976).

Wilderness Areas

The Park contains four legally proclaimed wilderness areas that comprise 48.5 percent (117,765 ha) of the Park. An additional 17 percent (41,388 ha) has been zoned as wilderness based on various criteria (Ezemvelo KZN Wildlife 2005b).

The wilderness areas are managed according to the Wilderness Area Management Plan (Ezemvelo KZN Wildlife 2005b) that forms part of the Integrated Management Plan (Ezemvelo KZN Wildlife 2005a) of the Park. Both management plans refer to the wilderness zones of the Park that were zoned using the Recreation Opportunity Spectrum (ROS) method (Clark and Stankey 1979; Buist and Hoots 1982).

Park Zonation

The zonation of the Park, according to the ROS, was undertaken as a desktop exercise based on the experience and knowledge of the management team. The ROS system enables the protected area to be zoned, in context, according to seven categories that are spread along a continuum from wilderness to rural recreational development: pristine wilderness, primitive wilderness, semi-primitive wilderness, semi-primitive non-motorized, semi-primitive motorized, roaded natural, and rural. Of the seven categories, the pristine wilderness, primitive wilderness and semi-primitive wilderness zones fall within the wilderness areas and collectively form the Wilderness Opportunity Spectrum (WOS) within the ROS. Each category within the WOS and ROS is defined in terms of activity, setting, and experience opportunities, which guides both the manager and the recreationist.

It is recognized that sections of proclaimed wilderness may no longer possess the wilderness qualities that allowed them to be designated as such over 30 years ago.

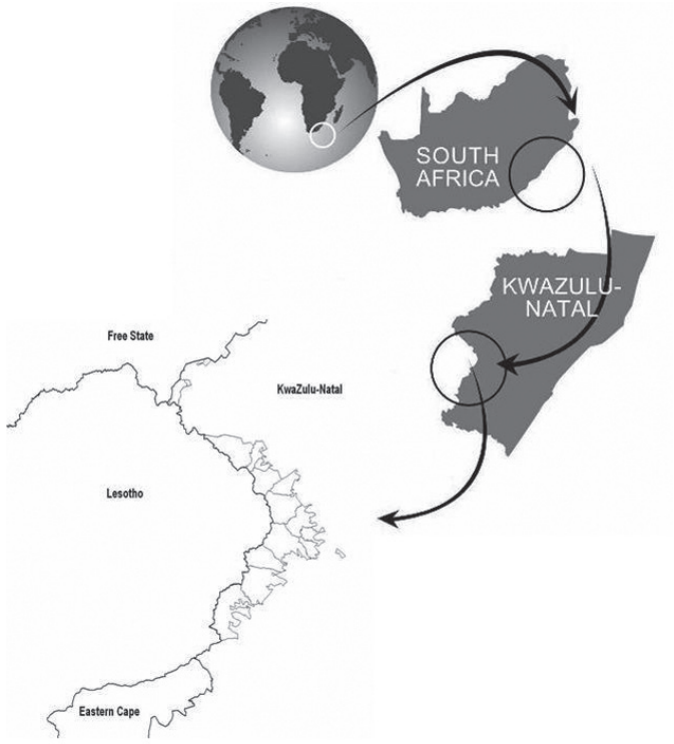

Figure 1—Location of the uKhahlamba Drakensberg Park World Heritage Site in the KwaZulu-Natal Province of the Republic of South Africa. Lines within the Park indicate separate management units.

Methods

The validation of the Park zonation was achieved using a Viewshed Analysis in a Geographic Information System (GIS) to analyze the extent of the existing visual impact of man-made features (developments) inside and outside the Park. A field based exercise to ground-truth the accuracy of the computer analysis at a series of random points was then conducted, with the categories of activity, setting, and experience opportunities assessed for each sample point.

Viewshed Analysis

The computer verification of the zonation categories took the form of a Viewshed Analysis using a Digital Terrain Model (DTM) to confirm the exact boundaries of the various zones digitally. The shuttle SRTM 90 m resolution DTM was used (Jarvis and others 2008). The Viewshed Analysis was calculated in ArcGis 9.1 (ESRI, Redlands, CA) using datasets containing information on the infrastructure and land use within and adjacent to the Park that may impact wilderness. Datasets representing the following man-made features were used: roads, paths, households, towns, medical facilities, schools, recreational facilities, buildings, powerlines (medium and high voltage) and landcover (built up areas). (Details of these datasets are available from the corresponding author.)

A model was run using shapefiles of the above infrastructure datasets to determine whether they had a visual impact on wilderness users in the Park. All data sets were clipped to a 20 km buffer of the Park boundary, which was taken to be the maximum visible distance from the Park boundary that would have a direct impact on the zonation of wilderness areas (Higuchi 1975). It was assumed that anything outside this range would not be visible and, therefore, would not have any direct impact on the zonation of wilderness areas. This reduced the number of points that would be used in the viewshed and significantly reduced computer processing time. All line features (e.g., roads and powerlines) were converted to point features using 1,000 m spacing for all points. Polygon features (e.g., timber plantations) were converted to point features by creating points at 100 m intervals along the polygon perimeter.

The Viewshed tool in ESRI's Spatial Analyst ArcToolbox allows for the inclusion of visibility parameters that can be added to enhance the Viewshed Analysis. Viewshed control parameters were included in the attributes of input shapefiles to include the height factor of both the observer points (e.g., the height of an average person) and the points within the dataset (e.g., the height of a building). Visual parameters denoting the range of human visual perception were also included. The parameter denoting the middle distance range of visibility was used. Visibility parameters that indicate the depth of human sight are not well-researched. Visibility is a variable factor that depends on an extensive number of inconsistent inputs such as weather and quality of sight of the observer. The indices of Higuchi (1975) were used because they were based on changes in weather conditions, and thus were found to be the most informative indices.

A Viewshed Analysis was run for each of the above mentioned datasets using a 20 m resolution DTM. All Viewshed Analyses were run using the same resolution, apart from the large 'households' dataset where a lower resolution was used (by multiplying the output raster cell size by 100) to reduce processing time. Following the viewshed process, each output file was reclassified into a Boolean format so that each cell showed either visible (1) or not visible (0).

To obtain an overall picture of the cumulative impacts of all observation features, the reclassified layers were summed using the 'weighted sum' tool in ArcGis 9.1. This tool allows the user to specify weights for multiple rasters, which are multiplied by their individual given weight and then summed together. Weights for each parameter were generated using the eigenvectors derived from a pairwise comparison matrix undertaken by a group of agency staff. The eigenvector of weights for the parameters used in this exercise were ranked from highest to lowest impact as follows; recreational accommodation (0.2995), towns (0.2725), roads (0.1369), households (0.1230), schools (0.0415), clinics (0. 0277) and powerlines (0.0159 and 0.0216 for medium and high voltage respectively).

Field Validation

The field validation exercise took the form of an accuracy test of the Viewshed Analysis. The field verification was conducted in six of the 15 management units of the Park. Four of the six management units had a pristine wilderness zone. Where possible, ten points were randomly generated in a GIS within each zonation category in each management unit. The manager navigated to each location using a Global Positioning System and verified the zonation category according to the description of the activity, setting and experience opportunities of that zone. A description of the attributes of the pristine wilderness zone is presented in table 1.

Results and Discussion

The numerical values in the output of the Viewshed Analysis indicate the number of separate features visible from that grid cell. Where the cell value is zero, there is no current visual impact from man-made features and accordingly where it would be possible, from a visual perspective, to have a pure wilderness experience (fig. 2). The weighted sum of visual impacts indicates that several areas currently proclaimed or zoned as pristine wilderness in fact have significant visual impacts from developments outside or inside the Park.

The Viewshed Analysis suggests that 24 percent (56,817 ha) of the Park is pristine wilderness whereas only 14 percent (34,026 ha) of the Park is currently zoned as pristine wilderness (table 2). In the Cobham management unit, pristine wilderness is predicted to be 19 percent (5,632 ha) of the size of the management unit, whereas only 8 percent (2,210 ha) was zoned as such. Similarly, in the Witteberg management unit, pristine wilderness is predicted to be 28 percent (6,307 ha) whereas only 5 percent (999 ha) was zoned as such. In the Injisuthi management unit, pristine wilderness is predicted to be 29 percent (4,551 ha) and only 11 percent (1,797 ha) was zoned as such. On the other hand, the predicted results for Hillside's pristine wilderness (21 percent, 2,205 ha) are similar to the actual results

Table 1—A description of the activity, setting, and experience opportunities for the pristine wilderness category in the uKhahlamba Drakensberg Park World Heritage Site.

Opportunity	Description of opportunities
Criteria or activity	Purest form, unmodified, no development, not impacted by any sights or sounds of people. No closer than 100 m to either side of existing trails. No formalized paths and no signage.
Setting descriptions	Area characterized by essentially unmodified natural environment of fairly large size. Area managed to be free from evidence of human-induced restrictions and controls. Motorized use not permitted. Interaction between users is very low, and evidence of other users is minimal.
Experience descriptions	Extremely high probability of experiencing isolation from the sights and sounds of humans, independence, closeness to nature, tranquility and self-reliance through the application of outdoor skills in an environment that offers a high degree of challenge and risk.

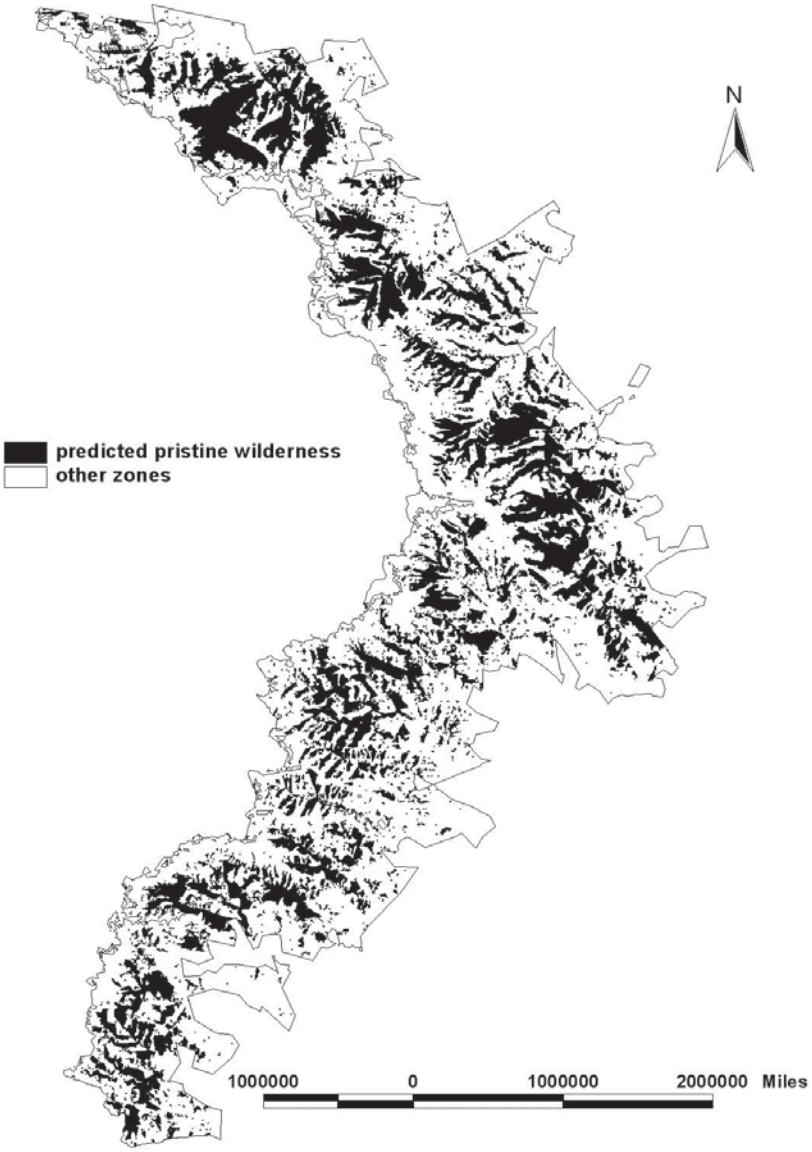

Figure 2—The results of the Viewshed Analysis indicating the predicted Pristine Wilderness areas of the uKhahlamba Drakensberg Park World Heritage Site.

Table 2—The percentage of zoned pristine wilderness compared to the predicted percentage of pristine wilderness.

Management unit	Zoned pristine wilderness	Predicated pristine wilderness
Cobham	8 (2,210 ha)	19 (5,632 ha)
Hillside	20 (2,095 ha)	21 (2,205 ha)
Witteberg	5 (999 ha)	28 (6,307 ha)
Injisuthi	11 (1,797 ha)	29 (4,551 ha)
Kamberg	0	19 (1,242 ha)
Rugged Glen	0	0.03 (0.24 ha)
The Park overall	14 (34,026 ha)	24 (56,817 ha)

(20 percent, 2,095 ha). Although no pristine wilderness was identified by managers in Kamberg management unit, the Viewshed Analysis predicted that 19 percent (1,242 ha) could be pristine wilderness. The results for the Rugged Glen management unit suggest that this area was zoned correctly; no pristine wilderness was identified and only a small amount (0.03 percent, 0.24 ha) of pristine wilderness was predicted.

The field verification exercise confirmed that for all six management units, the randomly selected points (n = 160) all conformed to the Park's existing zonation, thereby making it possible to compare actual to predicted zonation.

Overall, one third (33 percent, n = 15) of the points predicted to be in pristine wilderness were assessed in the field to be in pristine wilderness, whereas two-thirds (67 percent, n = 15) were predicted to be in non-pristine wilderness. The results for non-pristine wilderness were much better in that 88 percent (n = 145) of the points predicted to be in non-pristine wilderness were actually in non-pristine wilderness and only 12 percent (n = 145) were in pristine wilderness (table 3). However, a large amount of variation was experienced in the results between the management units.

Conclusions

This case study has detailed an approach used to validate the zonation of a protected area. Pristine wilderness was highlighted because no additional visual impact from developments would be tolerated in this zone and current impacts would be mitigated where possible. This study has focused on visual impacts in wilderness, and has not considered audio impacts. It is recommended that the audio impacts are also assessed when validating zonation boundaries.

The Viewshed Analysis predicts that a much larger percentage of the Park is pristine wilderness, nearly double the amount originally zoned. This prediction is, however, not substantiated in the field where only half the points predicted to be in pristine wilderness were assessed as being pristine. Based on the results, the analyses do not appear accurate enough for re-defining the pristine wilderness zones at the resolution of the DTM (90 m) used in this study. We surmise that the Viewshed Analysis is over-predicting the amount of pristine wilderness and, therefore, recommend that the Viewshed Analysis is revised and the highest possible resolution is used to run the model (20 m DTM based on 1:50,000 contour data is the highest resolution available for this area). Although processing time will increase significantly, it is necessary to run the model at the highest possible resolution to obtain the most accurate results where pristine wilderness is concerned. In addition, the field verification exercise should include a larger sample size of random points, particularly in pristine wilderness. One additional potential source of errors is the misallocation of zone category by the field assessors; therefore, it is essential that all persons undertaking the assessment are adequately trained to ensure consistency.

The areas identified in the revised analysis that are not impacted by man-made features will be demarcated and categorized as pristine wilderness. The pristine wilderness zone will then in turn be used to delineate the boundaries of the Park's buffer zone to ensure that wilderness values are protected, and opportunities to experience solitude and spiritual renewal exist. This will be undertaken by running a Viewshed Analysis looking from the re-defined wilderness areas outward to identify those currently undeveloped areas that need to remain undeveloped to maintain the current extent of wilderness. Once a buffer zone is demarcated, a buffer zone management plan and a combination of management interventions will be necessary to ensure achievement of the buffer zone objective of safeguarding wilderness values.

Table 3—The percentage of actual points from the field verification exercise that conform to the predicted zonation.

Zone	Predicted pristine wilderness	Predicted non-pristine wilderness
Assessed (actual) Pristine wilderness (n = 15)	33	67
Assessed (actual) Non pristine wilderness (n = 145)	12	88

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