esa ECOSPHERE

# The relevance of spatial variation in ecotourism attributes for the economic sustainability of protected areas

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**Abstract.** In contemporary society, protected areas are increasingly expected to justify their existence through the services that they provide to society. Protected areas offer many important cultural services, but appraisal of these nonmaterial benefits has generally proven difficult and most studies have focused on single case studies. Data on tourist numbers across multiple camps and protected areas provide a tractable and previously unexploited case study for better understanding the economic sustainability of cultural service provision and the relevance of potentially confounding variables (e.g., location and infrastructure) for park sustainability. We used redundancy analysis and linear models to relate a 5-yr monthly data set (2007–2012) of tourist numbers and tourism-derived income in all camps in South African national parks to a set of largely GIS-derived, determinant attributes that captured key elements of location, biodiversity, infrastructure, and accommodation cost at a camp level. Our analysis suggests that the degree to which cultural services can be converted into revenue for conservation is strongly contingent on infrastructure, location, and the business model that the park adopts. When considered alone, ecological attributes explained 14.2% and 3% of day and overnight visitation rates, respectively. In contrast, models that considered ecosystems in combination with other elements could explain 53% and 67% of variation. Linear models confirmed the existence of complex interactions between groups of variables and highlighted individual covariates that affected visitation rates. Significant variables included ecological features that provided aesthetic services, number of water bodies, elevation, available units, unit costs, and distance to the coast, airports, and other national parks. Taken in context our results suggest that it may be simpler than expected to make predictions about the potential future economic viability of protected areas under alternative models of management, illustrate how ecological variables may represent the "supply" side in cultural services, and highlight the complex interplay between ecological and built infrastructure. Encouragingly, this in turn suggests that relatively small, targeted investments in infrastructure could lead to disproportionate increases in tourist visitation rates and hence in increased revenue for conservation.

**Key words:** cultural ecosystem services; ecosystem services; ecotourism; national parks; natural resource management; nonmaterial benefits; protected areas; social–ecological systems; South Africa National Parks; spatial resilience.

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## Introduction

The decision to conserve or exploit a natural resource is strongly contingent on the social and economic values that society derives, or may derive, from that resource. Many of these values can be captured in the idea of services. Ecosystem Services (ES) are provided by ecological structures, systems, or functions that directly or indirectly contribute to human well-being (Boyd and Banzhaf 2007, Daniel et al. 2012). The Ecosystem Services (ES) framework, as adopted by the Millennium Ecosystem Assessment (Millennium Assessment 2005), was originally proposed as a formal approach for describing, categorizing, and valuing the ways in which societies depend on ecosystems (Mooney and Ehrlich 1997). In recent years, it has been widely accepted within the international environmental science and policy communities (e.g., Carpenter et al. 2009, Mace et al. 2012). In the process, the concept of ES has become a bridge between conservation and economics, in the sense that it allows ideas of ecological structure and function to be connected more rigorously to ideas of utility and value (Mäler et al. 2008, Daniel et al. 2012).

ES are defined in relation to human needs and are given their value by humans, and are thus effectively co-produced by people and nature (Gómez-Baggethun et al. 2013, Reyers et al. 2013). Most analyses of ES have focused on tangible services (such as pollination, carbon storage, or flood attenuation) that can be readily quantified (De Groot et al. 2002, Daniel et al. 2012, Hernández-Morcillo et al. 2013). However, many of the benefits that people derive from nature (and many of the values that inform resource use decisions) are intangible. Cultural ecosystem services are defined as "the nonmaterial benefits provided by ecosystems" (Millennium Ecosystem Assessment 2005) and includes such things as spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences. Despite their obvious importance, cultural services remain the least quantified of all ecological services (Rey Benayas et al. 2009, Daniel et al. 2012, Norton et al. 2012, Hernández-Morcillo et al. 2013). This is partly because attitudes toward ecosystem and cultural services vary widely and subjectively across the human population (Daniel 2001, Hagerhall 2001), and hence prove difficult to place consistent values on (Van Jaarsveld et al. 2005, Le Maitre et al. 2007). As a result, most studies have adopted a qualitative approach to measuring people's perceptions of various cultural services (e.g., Fagerholm and Käyhkö 2009).

While qualitative approaches can offer valuable insights, difficulties in quantifying cultural services mean that despite their underlying influence on decision-makers, cultural services are seldom integrated directly into natural resource management plans (De Groot et al. 2005). An additional problem is that assessments often consider only the supply of cultural services, not demand or access. The provision (and valuation) of cultural services should be understood both in terms of the potential value of the service, and the utilization of these services by society (De Groot et al. 2002, Robards et al. 2011, Gómez-Baggethun et al. 2013, Reyers et al. 2013). The relationship between supply and demand of cultural services is tenuous (Hernández-Morcillo et al. 2013), as it is influenced by an observer's social–cultural background, habits, and belief systems (e.g., Rambonilaza and Dachary-Bernard 2007, Bryan et al. 2009, Martín-López et al. 2012), as well as by objective factors relating to the ease of obtaining cultural services, such as location and accessibility (Hanink and White 1999, Wiggering et al. 2006, Martín-López et al. 2009).

Cultural services are particularly relevant to conservation efforts because of their high importance for protected areas. Protected areas have long been the dominant strategy for achieving conservation targets (Chape et al. 2005, Lockwood et al. 2006) and hence, environmental sustainability (Millennium Development Goal 7, Sachs 2005). Many protected areas owe their continued existence to the provision of facilities that allow visitors to obtain cultural services, such as game watching or solitude (Kettunen and Ten Brink 2013), that can best be provided by relatively intact ecosystems. The success of protected areas as conservation tools therefore depends in large part on their use (and hence, valuation) by the societies within which—and for whom—they were established. If the benefits of protected areas to society drive the creation and sustainability of protected areas, it is imperative that these benefits are quantified and communicated.

Ecotourism (which in this study is taken to mean the same as nature-based tourism) in protected areas offers one of the more tractable ways to quantify the economic benefits that are associated with cultural services (De Groot et al. 2002, Daniel et al. 2012). If ecotourism data are collected in similar ways by an overseeing management agency, such as a national parks service, spatial comparisons between protected areas can be used to assess how spatiotemporal heterogeneity affects the economic sustainability of protected areas (Daniel et al. 2012). The supply of cultural services is determined by the ecosystem and its intersection with local facilities, such as accommodation, restaurants, viewpoints, and roads (which may provide access to services such as recreational experiences, spiritual renewal, and solitude). The demand for cultural services can be quantified using the numbers of tourists and the amount of money that tourists spend on park entry and ecosystem use-related activities (De Groot et al. 2002, Martín-López et al. 2009).

Although the inherent or ecological value of a protected area is a key driving force for ecotourism (e.g. Dramstad et al. 2006, Chan and Baum 2007, Puustinen et al. 2009, Neuvonen et al. 2010), tourists generally look for more than just a great location (Seddighi and Theocharous 2002, Puustinen et al. 2009, Neuvonen et al. 2010). The probability of a tourist visiting a protected area depends initially on awareness of its existence. This knowledge is created through marketing campaigns, either directly or indirectly through word of mouth (Weaver and Lawton 2002, Lai and Shafer 2005). Tourists make decisions based on such variables as what they want to see or experience (e.g. Mills and Westover 1987, DeLucio and Múgica 1994, Hearne and Salinas 2002, Lindsey et al. 2007, Neuvonen et al. 2010,), how accessible a park is (Boxall et al. 1996), its facilities (Hearne and Salinas 2002, Puustinen et al. 2009, Vanhatalo 2009, Neuvonen et al. 2010), and their budget (Seddighi and Theocharous 2002, Alpízar 2006). Distances to national roads and airports and/or major population centers may weigh heavily in the decision to visit a particular park rather than another that may be less accessible (e.g., Hanink and White 1999, Hanink and Stutts 2002, Hearne and Salinas 2002, Neuvonen et al. 2010). Different demographics and types of tourist (Weaver and Lawton 2002, Lindsey et al. 2007) may also be attracted by different "pull" factors (Chan and Baum 2007) and specifically targeted facilities (e.g., camping, swimming pools, beaches, fishing jetties, bars, etc.) (Weaver and Lawton 2002, Mehmetoglu 2005).

In reality, ecological, economic, and logistical factors do not act in isolation from one another. For example, in Australia, seasonal rains may cause floods that render roads impassable and dampen visitation rates to northern protected areas. On the other hand, rainfall may cause large wetlands to fill in response to high discharge in rivers, which can generate spectacular growth in wildlife populations that serve as strong tourist attractors (Hadwen et al. 2011). In this study our aim was to quantitatively assess the use of ecotourism-related cultural ecosystem services on a broad spatial scale as a function of built and ecological infrastructure, and the interaction between them. We therefore hypothesized that actual cultural service provision should be heavily influenced by strong interaction effects between access and potential cultural service provision, as a result of ecotourists making trade-off decisions between travel time, their desire to see or experience particular elements of nature, and the economic expense involved. Alternatively, either access (connectivity and expense) or potential cultural services (the nature of the ecosystem and related facilities) might dominate other concerns, in which case we would expect strong relationships of ecotourism to individual variables and insignificant interaction effects between different kinds of variable.

We used tourist visitation data and a set of other potential explanatory variables from South African protected areas to distinguish between these hypotheses. These socio-economic and biophysical data are representative of information routinely collected by natural resource management agencies around the world, and on a practical level, we were interested in exploring their potential for quantifying the use of cultural services in protected area management. South Africa, with its diverse and growing ecotourism industry and sprawling geography, offers a potentially insightful case study from which to better understand the relevance of spatial variation in protected area location and infrastructure for usage of the cultural services that protected areas offer. We were particularly interested in the question of whether, and how, the addition of convenience-related infrastructure (e.g., airports, accommodation, restaurants) to a protected area might influence apparent demand for cultural services. Although the potential supply of cultural services is determined primarily by the ecosystem,

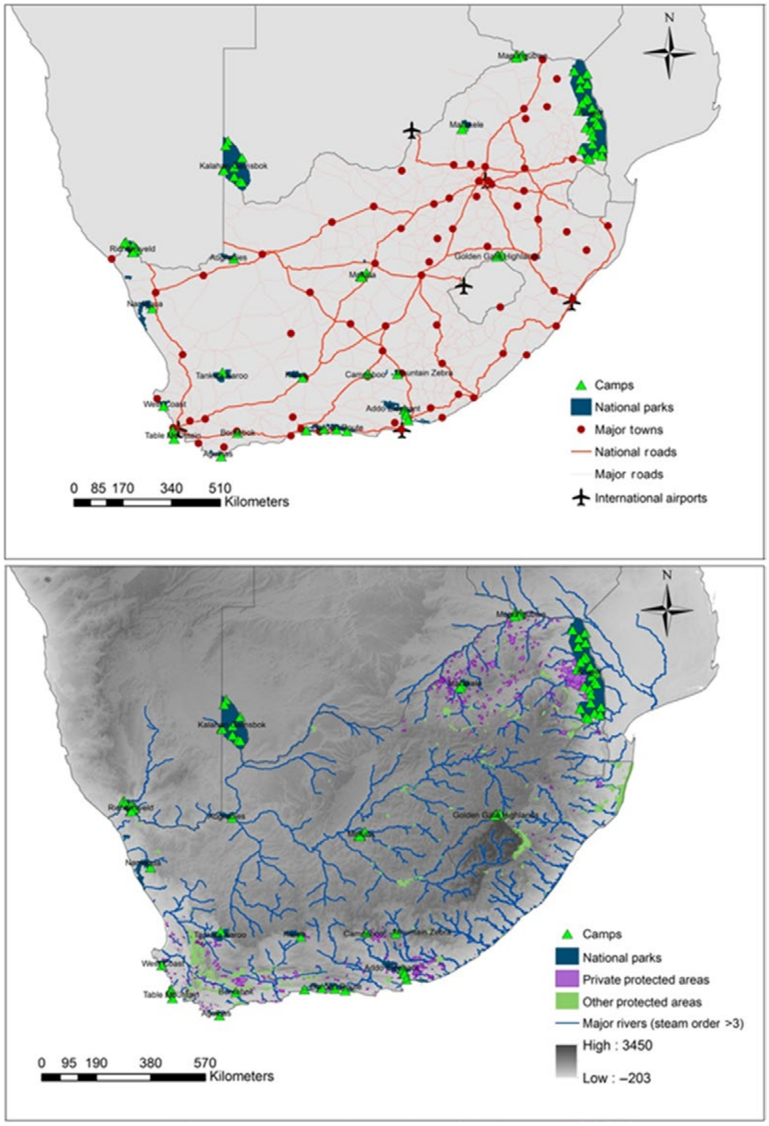


Fig. 1. Map illustrating South African national parks and their tourist camps, as investigated in this study. This map also shows the context of these areas in terms their location relative to national (thick red line) and main (soft red lines) roads, airports, and major towns (red dots). The map on the right shows protected areas in context of some of the major natural features, including major rivers (stream order >3, thick blue line), elevation (graduated shades of gray), and other protected areas (private protected areas = purple, other statutory areas = green).

we expected to find that the degree to which cultural services can be converted into revenue for conservation would be strongly contingent on infrastructure, location, and the business model of the park. Understanding the relative strengths of these influences has important implications for individually tailoring management actions to make national parks economically self-sufficient.

## Methods

We considered all 91 camps in 19 of South Africa's 20 national parks (Fig. 1) in our analyses. The 20th is Groenkloof, the location of the administrative head office of South African National Parks ("SANParks," South Africa's national parks management authority), which

Table 1. Summary of visitor numbers and income from tourists, as well as measured elements of infrastructure (e.g., number of units/camp), location (e.g., distance to airports), and ecology (e.g., size) for four of South Africa's 19 National Parks. Average values are displayed with standard deviations, absolute values without. A more comprehensive table with values for all parks and measured features can be found in Appendix A.

| | Visitor numbers and income from tourists | | Infrastructure | | Location | Ecological features | |
|---|---|---|---|---|---|---|---|
| South African National Park | RevPAR (ZAR) | Units occupied | Units/camp | Road Length (km) | Time to nearest international Airport (Min) | Size (km²) | Areas of inland water bodies (km²) |
| ADDO | 331.14 ± 183.64 | 66.72 ± 20.93 | 26.6 ± 25.04 | 344.264 | 62.36 ± 19.22 | 1708 | 5555.44 |
| RICHTERSVELD | 67.51 ± 75.25 | 19.86 ± 20.77 | 8.74 ± 3.81 | 357.65 | 632 ± 68.53 | 1798 | 49.54 |
| KRUGER (SOUTH) | 290.01 ± 231.71 | 72.3 ± 22.03 | 59.12 ± 53.22 | 4355.932 | 282.16 ± 32.52 | 18989 | 1605.33 |
| TANKWA KAROO | 146.77 ± 154.13 | 29.74 ± 21.41 | 9.97 ± 2.77 | 384.03 | 296 | 1357 | 718.94 |

Table 2. Summary of the variables measuring day and overnight visitor numbers in South African national parks.

| Variable | Description |
|---|---|
| Accommodation Type | Camping or Chalet |
| max_potent | Maximum Potential revenue, in South African Rand (ZAR) |
| units_av | Total number of units available |
| av_max_pot | Average maximum potential |
| units per night | Units available per night |
| units per night sold | Units per night sold |
| units occupied | Occupancy rate |
| av length of stay | Average length of overnight visitor stay |
| average accommodation charge | Average accommodation charge |
| avg rate/unit | Average rate per unit |
| RevPAR | Revenue per available room |
| RevPAR_per | Revenue per available room per person |
| Gate_arr | Total gate arrivals |
| Day visitors | Total day visitors |
| RSA visitors | Total South African visitors |
| Overnight visitors | Overnight visitors |
| RSA Overnight visitors | Total South African visitors |

is a small patch of land in the center of Pretoria (South Africa's administrative capital). We considered the units of analysis to be "camps" rather than "parks", as there is a significant amount of heterogeneity in camp character and visitation rates in some of the larger parks, such as between northern and southern camps of the Kruger National Park.

Protected area boundaries and tourist visitation rates were obtained from SANParks, and spatial coordinates for camps from Tracks4Africa. Using GIS software (ArcGIS10, ESRI 2011), Google Maps, Google Trends, spatial data sets and species lists, we derived, by camp and protected area, a range of ecological, biophysical, location, infrastructural, and marketing-related variables that might explain visitation rates to a given camp. A summary overview of these data, by park, is provided in Table 1 (a more complete version of this table can be found in Appendix A). Tables 2 and 3 provide a summary and definitions of economic variables and potential correlates considered in this study, respectively. We compared these data between different camps to test for spatial influences on tourist visitation rates.

Table 3. Summary of variables considered as potential correlates of tourist numbers and income from tourists.

| Type | Variable | Description |
|---|---|---|
| Location | International Airport | Travel time by road (min) from camp to nearest International airport |
| | Local Airport | Travel time (min) from camp to nearest local airport |
| | Nearest Town | Travel time (min) from camp to nearest town |
| | Nearest National Road | Travel time (min) from camp to nearest national road (N/R) |
| | Nearest National Park Camp | Travel time (min) from camp to nearest national park camp |
| | Nearest Coast | Travel time on roads to the nearest point on the Southern African coastline (including Namibia and Mozambique) |
| | Park Area | Area of the park in $km^2$ |
| | Close National parks | Number of national parks within a 100 km of national park boundary |
| | Close Private Protected Areas | Number of private protected areas within 100 km of national park boundary |
| | Close Provincial Parks | Number of provincial and other reserves within 100 km of national park boundary |
| Discoverability | City search | Median distance of cities with high Internet search traffic (search index >1) for the park |
| | Average Google Trends Search | Average Internet search index recorded for the park, relative to “Table Mountain” |
| | Variance in Google Trends Search | Variance in Internet search index recorded for the park, relative to “Table Mountain” |
| Ecological Value | Points of Interest (POI) | Total number of “Points of Interest” within a 50 km buffer of the camp |
| | Ecological POI- Aesthetic | Total number of “POI”s classified as “Ecological infrastructure” related to aesthetic services in a 50 km buffer area from camp |
| | Ecological POI -Recreational | Total number of “POI”s classified as “Ecological infrastructure” with the potential of providing recreational services in a 50 km buffer area from camp |
| | Ecological POI Wilderness | Total number of “POI”s classified as “Ecological infrastructure” related to wilderness experiences in a 50 km buffer area from camp |
| | Number of Inland Water Bodies (park) | Total number of inland water bodies within the boundary of the national park. |
| | Number of Inland Water Bodies (camp) | Total number of inland water bodies within a 50 km camp buffer zone of a camp. |
| | Area of Inland Water Bodies (park) | Total area of inland water bodies within the boundary of the national park. |
| | Area of Inland Water Bodies (camp) | Total area of inland water bodies within a 50 km camp buffer zone |
| | Perimeter of Inland Water Bodies (park) | Total perimeter of inland water bodies within the boundary of the national park. |
| | Perimeter of Inland Water Bodies (camp) | Total perimeter of inland water bodies within a 50 km camp buffer zone |
| | River Length (park) | Total length of rivers (m) within the boundary of the national park |
| | River Length (camp) | Total length of rivers (m) within a 50 km buffer of the camp |
| | Number of the Big Five | Number of big five recorded in the park (Buffalo Elephant, Buffalo, Lion, Rhino) |
| | Number of Mammal Species | Total number of mammal species recorded in the park |
| | Number of Bird Species | Total number of bird species recorded in the park |
| | Elevation | Elevation of camp above sea level |
| | Enhanced Vegetation Index (EVI) | Enhanced Vegetation Index using Landsat 8 |
| | Land Cover Classes | Total number of land cover classes within park boundary |
| | Land Cover Diversity | Shannon Diversity of land cover classes within the parkboundary |

Table 3. Continued.

| Type | Variable | Description |
|---|---|---|
| Infrastructural Value | Built Infrastructure POI- Ecological Assets | Total number of points of interest classified as built infrastructure contributing to the enjoyment or facilitating the use of the parks ecological assets |
| | Built Infrastructure POI- Comfort and visitor experience | Total number of points of interest within 50 km buffer of camp classified as "built infrastructure" |
| | Road Length | Total length of roads (m) in the park |

### *Economic data*

SANParks provided monthly data for all camps from January 2007 to December 2012. The number of units available, the number of units sold, occupation rates, unit costs, and revenue generated per available rooms were available for the entire period. Daily visitors, gate arrivals and overnight visitors, broken down by local and international visitors, as well as conservation fees generated and wild cards sold (wild cards indicate membership in SANParks' loyalty program), were available from January 2010 to December 2012.

There was inconsistent reporting between parks and camps and not all data categories were available for the complete period. We dealt with this by employing standard data inspection techniques (e.g., Zuur et al. 2010), manually removing variables and individual records that were deemed unsuitable or suspicious. We used boxplots to check for outliers and frequency plots to check for zero inflation, subsequently inspecting data manually to identify plausible large and zero values. Values that were deemed to be data errors were manually removed. Finally, we removed all incomplete records from the data set, reducing the total number of records by 28.5% from 6276 to 4486.

### *Ecological and infrastructural points of interest*

Tracks4Africa is a company that creates GPS maps from community-submitted tracks and points of interests. We were provided with 11,399 points of interest, in 132 categories, for all 19 national parks, and all 91 camps extracted, by camp, from the full Tracks for Africa data set as on 31 December 2012. An online version of these data can be viewed at http://tracks4africa.co.za/maps/africa/.

Although data can be submitted to Tracks4Africa for any place in Africa, data are particularly good for South African national parks. Points of interest (POI) are submitted largely by visitors to these parks, thus features inherently represent a degree of utility. We reclassified the original 132 categories, lumping very similar ones (e.g., "Airport" and "Heliport"). We then classified each category type as being an ecological interest (EI) or infrastructural (built interest, BI) feature that would produce an aesthetic, recreational, or experience-of-wilderness cultural service. These three categories of cultural services are those most commonly associated with ecotourism (Ode et al. 2008, Hernández-Morcillo et al. 2013).

We tallied points of interest, designating each as (1) EI_aes (a category feature that could provide an aesthetic service, e.g., a POI classified as "Viewpoint"), (2) EI_wil (a feature category that could provide an experience of wilderness, e.g., "Botanical"), (3) EI_rec (a feature category that could provide a recreational service, e.g., "Paragliding"), or (4) BI (a built infrastructure point of interest, e.g., "Pontoon"). We scored each feature category as 1 if it could likely provide a service under any of these classifications, and 0 if it did not fit that category well. The complete classification is provided in Appendix B. All classification was done by the lead author (ADV).

We then overlaid the reclassified point data with the camp point data set and calculated the total number of POI within 50 km of the camp under each classification. A distance of 50 km was selected because it is the average daily distance that game viewing vehicles were found to travel in protected areas in the Eastern Cape of South Africa (Maciejewski 2012).

### *Landscape and vegetation*

Using ArcMap 10 to extract land cover classes from the South African National Land Cover Data Set 2000 (Van den Berg et al. 2008) and Vegetation Map of South Africa (Mucina and Rutherford 2006) for each national park, we calculated the total number of land cover classes and the Shannon diversity index as a proxy measure of landscape aesthetics (Ode et al. 2008, Casalegno et al. 2013).

The Shannon diversity index quantifies diversity within a defined area based on two components: the number of different patch types (in this case, a land cover class would constitute a patch type) and the proportional area distribution among patch types. The Shannon index is calculated by adding the proportion of area covered for each patch type present, multiplied by that proportion expressed as a natural logarithm. Both indices will be higher if the landscape is more topologically varied and if it contains a greater variety of different kinds of vegetation; we speculated that visitors might prefer parks that contain a diverse array of habitats (e.g., montane, lowland, forest, grassland, etc.) to those that offer less variation, as have been shown elsewhere (e.g. Dramstad et al. 2006, Neuvonen et al. 2010).

Additionally, as some studies have shown that tourists prefer to stay in areas with lusher vegetation (Eleftheriadis et al. 1990, Múgica and De Lucio 1996), we calculated the mean EVI (Enhanced Vegetation Index) for camps from the Landsat 8 EVI annual composite layer, downloaded from Google Earth Engine: http://earthengine.google.org, ID LANDSAT/LC8_L1T_ANNUAL_EVI.

### *Rivers and wetlands*

Water attracts animals, provides recreational experiences, and is aesthetically pleasing (Nassauer et al. 2007). We used two data sources to quantify the presence of water around camps, and within parks: a modified version of the DWAF 2000 data set (by GSC, 1:50000) and the river layer from the South Africa's National Freshwater Ecosystem Priority Areas project (1:500000, 2011, SANBI, DWA, WEC, WWFSA, SANParks, SAIAB, available at http://bgis.sanbi.org/nfepa/project.asp). We again applied a 50 km buffer.

### *Biodiversity*

Charismatic wildlife (carnivores and megaherbivores) is a big draw-card for international and some local tourists (Kerley et al. 2003, Lindsey et al. 2007, Maciejewski and Kerley 2014), while many more experienced local tourists, returning international tourists, or special-interest visitors show a greater interest in bird and plant diversity, as well as less high-profile mammal species (Lindsey et al. 2007). We thus obtained mammal and bird species lists from the SANParks website, or, if not available here, from national parks' ecological managers (for Garden Route, Marakele, Mapungubwe, Mokala, Table Mountain National Park). We used these to calculate the total number of mammal, bird, and "big five" (elephant, rhinoceros, buffalo, lion, leopard) species found in each park, considering black and white rhinoceros as a single "big five" species in this instance.

### *Elevation*

We calculated the elevation of each camp by extracting its height in meters from the SRTM (Shuttle Radar Topography Mission) Digital Elevation Data Version 4 (NASA/CGIAR, 2000, Image ID CGIAR/SRTM90_V4) data set, in ArcMap 10.

### *Roads and number of chalets and campsites*

In addition to the infrastructural points of interest calculated from the T4A data set, we also calculated, from the same source, the total length of roads within a park and within a 50 km radius of a camp. The SANParks tourism data included the number of chalets and camping spots.

### *Spatial variables*

*Accessibility.*— We used the shortest commuting time (in minutes) between camps and various points of infrastructural access variables (international and local airports, other camps, nearest town, nearest point at the coast) as calculated in Google Maps as a proxy for accessibility. Google Maps calculates the time travel between two points based on the fastest route taking into account traffic (near urban centers), the speed limit, and road speed index (a proxy for road condition).

Lastly, we calculated the total number of national parks, provincial reserves (as per the 2012 protected area register, available from the Department of Environmental Affairs), and private protected areas (data for these areas were provided from DEA, provincial spatial planners, and provincial gazettes) within 100 km buffer of each camp.

### *"Discoverability" variables*

To measure how "discoverable" a protected area was internationally (i.e., as a proxy to get at marketing strategies), we used metrics produced by Google Trends (www.google.com/trends/explore). Google Trends analyses a portion of Google web searches to compute how many searches have been done for the terms entered, relative to the total number of searches done on Google over time, or relative to the number of times a comparative search term has been entered over time. The application designates a certain threshold of traffic for search terms, so that those with low volume do not appear. The system also eliminates repeated queries from a single user over a short period of time.

We used "Table Mountain" (the name of one of South Africa's key tourist attractions, as well as one of its most visited National Parks) as a fixed search term against which we compared the names of other national park names as search terms, setting the time of analysis to coincide with our data set (2007–2012). From the downloaded csv file, we calculated the mean and variances of proportions computed over this time. We used Google Maps to calculate the average distance, from camps, of the cities that emerged as contributing the most to search interest of each park.

### *Data analysis*

We divided the variables *a priori* into six broader categories for analysis: "Location" (6 variables), "Ecology" (14 variables), "Discoverability" (3 variables), "Infrastructure" (6 variables), "Affordability" (2 variables), and "Time" (2 variables) (see Table 3).

The ecological group included elements of biodiversity, surface water, ecological points of interest, elevation, and area as described in the proceeding section. The "location" and "discoverability" groups equated to the variables described above under the "spatial variation" and "discoverability" headings, respectively, while the "infrastructure" group comprised infrastructural points of interest from the Tracks4Africa data set, as well as roads and available units. Finally, the "affordability" group was derived from two variables from the economic data set, namely accommodation charge and unit cost and "Time" and included month and year.

Prior to analysis we checked and cleaned the data, as described in the preceding section.

Collinearity within covariates was examined, and where a pair of covariates exceeded a threshold of 0.4, a single variable was removed. Many variables, particularly in the ecological group, were inter-related. Our goal was to assess the kinds of factor potentially influencing tourists, rather than to identify specific drivers (we wanted to know, e.g., whether the combination of biodiversity and access to the park is an important factor; rather than whether, specifically, the number of bird vs. number of mammal species or distance to nearest national road vs. distance to town were the more important descriptors of these relationships). The nature of the data was also such that it was statistically inappropriate to correct for the effect of any single variable through the use of residuals. We therefore picked variables to include in each analysis based on the conceptual models that we considered feasible or interesting, rather than attempting to work simultaneously with all variables.

### *Redundancy analysis*

To assess broad patterns and interactions, we first performed a redundancy analysis (RDA), the canonical version of principal components analysis, to find the proportion of variation in the economic data that could be explained by each of the factor groups (see Table 4). For the economic response data, we differentiated between day and overnight visitors. Variables that were considered measures of day visitor rates were "conservation fees" and "gate arrivals", while "overnight numbers", "number of units sold", "occupation rate", "RevPAR" (Revenue per available room), and "RevPARper" (Revenue per available room per person) were judged to be appropriate measures of overnight visitor rates.

The varpart function, a component of the "vegan" package in R (Oksanen et al. 2013) uses redundancy analysis ordination to partition variation in a response table (in this case visitation rates) into pure and shared explanatory fractions

Table 4. Results of a redundancy analysis performed on ecological, location, affordability and infrastructure prediction tables against day visitor and overnight visitor response tables. The table shows significance of individual fractions tested with 199 permutations under a full model.

| | Adj $R^2$ | df | dAIC | $F$ | Pr(>$F$) |
|---|---|---|---|---|---|
| Day visitors | | | | | |
| Ecology | 0.146 | 11 | 1193.1 | 126.189 | 0.005** |
| Location | 0.021 | 7 | 188.6 | 29.443 | 0.005** |
| Affordability | 0.020 | 2 | 82.4 | 43.366 | 0.005** |
| Infrastructure | 0.071 | 3 | 625 | 224.636 | 0.005** |
| Overnight visitors | | | | | |
| Ecology | 0.030 | 11 | 378.43 | 37.873 | 0.005** |
| Location | 0.005 | 7 | 63.62 | 11.125 | 0.005** |
| Affordability | 0.174 | 2 | 1886.34 | 1169.203 | 0.005** |
| Infrastructure | 0.040 | 3 | 511.39 | 181.823 | 0.005** |

contributed by two to four explanatory tables. As this technique only allow for the inclusion of up to four explanatory groups, we ran an exploratory RDA models with all six groups, and performed exploratory variance partitioning with different combinations of explanatory tables. As "time" and "discoverability" were consistently found to contribute the least explanation toward variation in visitation rates (<1%, compared to significantly higher values from other groups), these were excluded from the final coarse-scale analyses, as reported in the results. This results table decomposed the variance into 4 pure and 11 shared logical components. To assess the significance of the contribution of each of the pure and shared fractions, we performed ANOVA-like significance tests with 199 permutations under the full model.

### *General linear mixed models*

We used generalized linear mixed models (GLMMs) to identify which covariates affected day visitation in National Parks of South Africa, as measured by "gate arrivals". As our goal was to derive a general understanding of the individual factors that drive visitor rates, we wanted to use a response variable that captured elements of both overnight and day visitor rates. Thus, we chose "gate arrivals", which combined day and overnight visitor rates for camps.

The recent financial recession was hypothesized to have influenced the number of visitors to National Parks. We accounted for this in our model by adding a "recession" term, with four levels; prerecession (Jan 07 to Aug 08), recession (Sep 08 to Dec 08), postrecession (Jan 09 – Aug 10), and current (Sep 10 to present).

### *Model structure*

The primary analyses goal was to model gate arrivals as a function of the categories we created (namely "Location", "Ecology", "Discoverability", "Infrastructure", "Affordability"), as well as to identify which categories most affected the response. Firstly, we ran a model including all the variables within each category (Table 5), which we refer to hereafter as the "full model". Thereafter, we tested the affect each category had on the response by sequentially removing each category (and its associated variables) from the full model, and rerunning it (Table 6). We also ran an intercept only model, for reference. As we had five categories, we ended up with seven models (one model for each category removed from the full model, one intercept only model, and the full model). We used AIC to compare which model fit best within the pool of candidate models.

We made use of a random effect that accounted for variance across space and time. We created a variable which was a combination between the month and year from which the recorded gate arrivals came, and the Site (Park). Within this we nested "Camps" (the name of the campsite within the Park), because certain Camps only occur in certain Parks and observations from Camps from certain Parks are likely to be similar. Each model included this nested random effect, and was run with a Poisson distribution.

Table 5. Model Selection and candidate models. Model 1 details the full model, in which all the model covariates are included (see Table 3 for all model covariates). Models 2 to 6 detail the performance of models when one of the five categories considered to affect the number of daily visitors is removed from the full model (see Methods text for more information). AIC is the AIC score of each model (a lower AIC indicates a better fit), Δ AIC indicates the difference in AIC scores between each model and the best supported model, and k indicates the number of model parameters. Each model was run with a nested random effect, encapsulating variance attributed to space and time (see Methods text; random effect variances not shown).

| Model | Model Structure | AIC | Δ AIC | *k* |
|---|---|---|---|---|
| 1 | Full Model | 39254.9 | 0 | 24 |
| 2 | Discoverability removed | 39297.69 | 42.79 | 23 |
| 3 | Infrastructure removed | 39351.58 | 96.68 | 20 |
| 4 | Location vars removed | 39464.65 | 209.75 | 19 |
| 5 | Ecology removed | 39558.01 | 303.11 | 18 |
| 6 | Affordability Removed | 40712.9 | 1458 | 19 |
| 7 | Intercept Only | 42427.54 | 3172.64 | 3 |

Table 6. Model coefficients for the full model (best supported model) which included all categories.

| Category | Variable Name | Estimate | SE | *z* | *P* |
|---|---|---|---|---|---|
| | (Intercept) | 4.60 | 0.10 | 46.98 | <0.05 |
| Ecological | EI.AES | 0.22 | 0.03 | 7.16 | <0.05 |
| | TOT.IWB.50 | −0.29 | 0.05 | −5.74 | <0.05 |
| | Area.IWB.50 | 0.35 | 0.06 | 5.99 | >0.05 |
| | Rv.Ln.50 | −0.14 | 0.05 | −2.71 | <0.05 |
| | Lc.div | −0.34 | 0.05 | −6.90 | <0.05 |
| | Big.Five | 0.94 | 0.07 | 12.62 | <0.05 |
| Location | Int.Air | 0.05 | 0.07 | 0.66 | >0.05 |
| | Near.Camp | −0.04 | 0.05 | −0.85 | >0.05 |
| | Near.Coast | −0.52 | 0.06 | −8.94 | <0.05 |
| | Elevation | 0.26 | 0.06 | 4.31 | <0.05 |
| | NP.100 | 0.36 | 0.08 | 4.43 | <0.05 |
| Infrastructure | Units.av | 0.15 | 0.03 | 4.82 | <0.05 |
| | Rd.length | −0.78 | 0.11 | −7.21 | <0.05 |
| | Accom Type 1 | −0.48 | 0.14 | −3.35 | <0.05 |
| | Accom Type 2 | −0.88 | 0.16 | −5.39 | <0.05 |
| Affordability | Recession 2 | 0.07 | 0.11 | 0.65 | >0.05 |
| | Recession 3 | 0.04 | 0.07 | 0.54 | >0.05 |
| | Recession 4 | −0.05 | 0.07 | −0.76 | >0.05 |
| | Avg accom charge | 1.23 | 0.03 | 43.03 | <0.05 |
| | Avg Rate Unit | −0.16 | 0.07 | −2.39 | <0.05 |
| Discover | City Search | −0.71 | 0.11 | −6.72 | <0.05 |

## Results

### *Redundancy analysis and variance partitioning*

Results of the redundancy analysis and variance partitioning showed the fraction of variation in (a) day and (b) overnight visitor rates that could be explained by different factor groups, namely "location", "ecology", "infrastructure", and "affordability" (Fig. 2a,b). The combined models explain 53% and 67% of the variation, respectively, leaving 47% and 33% of the variation in the economic data attributed

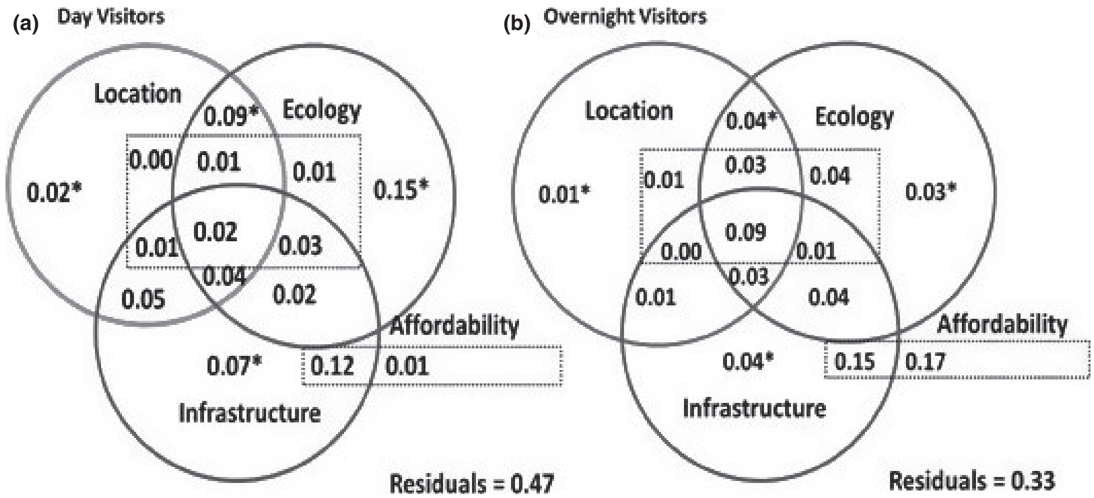


Fig. 2. Diagram illustrating the proportion of variation ($R^2$ adjusted) in (a) daily visitation rates and income (as measured by number of gate arrivals and conservation fees) and (b) overnight visitation rates and income (occupation rates, overnight numbers, RevPAR and RevPAR per person) that is explained by the pure and shared fractions of variation in elements of location, ecology, infrastructure, and affordability. *P*-values showing the significance of each fraction of variation were estimated with 199 permutations under the full model. ***$P < 0.001$, **$P < 0.01$; *$P < 0.05$. Insert boxes show the combined values of the main groups and all their interactions, for example: Location = Location + Location * Ecology + Location*Infrastructure, Location*Affordability, etc. As interactions contribute to more than one group (e.g. "Location*Ecology" will contribute to values for both "Location" and "Ecology"), the totals presented in the insert adds up to >1.

to unidentified factors. In the following results, the variation explained in each RDA model is reported as the adjusted $R^2$ ($R^2$ adj), which accounts for the inflation of $R^2$ values associated with the number of predictor variables and sample size.

Of the four different groups, and their interactions, ecological variables and infrastructure explained the most variation in day visitation rates (14.6% and 7.1%, respectively), while affordability and location explained 2.1 and 2%. The interaction between ecology and location, and ecology and infrastructure and ecology explained 9.3% and 2.4% of variation, respectively, while the interaction between location and infrastructure, and affordability and infrastructure explained 5.0% and 11.6% of variation, respectively. The interaction between infrastructure, ecology, and affordability explained 3.0%.

For overnight rates, the strongest predictor of variability was affordability (17.4% variation). Ecology explained 3.0%, infrastructure 4.0%, and location 0.05%. The interactions between ecology and affordability, ecology and location, and ecology and infrastructure explained 4.0%, 4.3% and 3.4% of variation, respectively, while the interaction between location and infrastructure explained 14.7%. The interaction between all four groups explained 8.9%, while the interaction between ecology, location and the interaction between infrastructure, and ecology, infrastructure and affordability explained 4.2% and 4.3%, respectively.

### *General linear mixed models*

The mixed model (Table 5) was complementary to the redundancy analyses in that it also showed that time of year was not a significant predictor of visitor variation. Similar to the variance partitioning, the linear models showed that visitor numbers are influenced by a combination of drivers. In seeking to identify individual covariates that might be strong drivers of visitation rates, they supported some of the broader patterns identified by the RDA result. Of the five different candidate models considered, "Affordability" variables affected model fit most strongly (ΔAIC=1458), followed by

"Ecological" variables (ΔAIC =303.11), Location (ΔAIC =209.75), and Infrastructure (ΔAIC =42.79).

Analysis of the coefficients of different candidate models supported the redundancy analysis by clarifying the specific contribution of different feature types. Of the ecological features, Ecological POI, land cover diversity, inland water bodies, and the number of big five present had significant coefficients ($P < 0.05$)(Table 5). For location, coefficients that contributed significantly to model fit were distance to coast, elevation, and the number of other national parks within a 100 km of the camp. Of the infrastructure variables, "Number of units available", "Accommodation type 1 and 2", and the total road lengths all contributed significantly ($P < 0.05$). "Average rate per unit" and "unit costs" were both significant "affordability" coefficients ($P < 0.05$), was and correlated negatively with visitation (Table 5). "Citysearch" was the only discoverability variable retained in the model, and was found to significantly and negatively contribute to model fit ($P < 0.05$; Table 5).

## Discussion

We were able to explain a significant proportion of the variation in tourist numbers to South African National Parks, and in tourism-generated revenue, using a relatively small number of readily quantified variables. Our analysis indicated that visitor numbers were heavily influenced by elements of the location of a national park, its ecological features, affordability, and available infrastructure. The relative importance of each of these factors appeared to depend, as might be expected, on the type of tourist visiting the park; different factors influenced variation in day and overnight visitation rates, respectively. Day visitor numbers, and the income derived from day visits, were best explained by ecological and infrastructure variables. These were followed by affordability and location, which also played important roles. By contrast, the majority of variation in overnight visitation rates and revenue could be explained by affordability variables (mostly accommodation cost), followed by infrastructure, ecology, and location variables. We therefore found strong support for the interaction hypothesis, which suggests that actual cultural service provision is heavily influenced by the interactions of access and potential cultural service provision rather than being a simple consequence of ecosystems contained within the PA.

The results of the general linear model analysis, which focused on total arrivals (day and overnight) at camps, confirmed that variation in visitor numbers was driven by a combination of drivers and highlighted covariates that contributed significantly to this variation. Ecological factors that explained a lot of variation in day visitor numbers were the number and total area of inland water bodies present near a camp, as well as the ecological features that were deemed significant to mark as points of interest (i.e., those, such as lookout points or waterfalls, that provided an aesthetic cultural service). Interestingly, the number of inland water bodies varied negatively with visitor numbers (this point is discussed in more detail later). At the level of the covariates, it appeared the elements of location were by far the strongest contributors to explained variation. Increased distance (or travel time) to international airports and the coast, and a higher elevation all affected visitation rates negatively, while the number of nearby camps had a positive effect. In terms of affordability and available infrastructure, "average rate per unit charged" and "available units" both significantly affected visitation in a negative and positive way, respectively.

Ecotourism has been proposed in many parts of the world as a win–win solution for poverty alleviation that generates revenue from common property resources in a sustainable way (Spenceley et al. 2002, Chape et al. 2005). Taken in context, our results identified several interesting trends and patterns that have important local and international implications for both the economic viability of protected areas and alternative approaches to managing demand for cultural services.

First, our analysis suggests that a variety of complex factors influence ecotourism decisions in South African national parks, not unlike in Finland (Puustinen et al. 2009, Vanhatalo 2009, Neuvonen et al. 2010, Nerg et al. 2012), Norway (Mehmetoglu 2005), Australia (Weaver and Lawton 2002), Spain (DeLucio and Múgica 1994), Costa Rica (Hearne and Salinas 2002, Alpízar

2006), Malaysia (Chan and Baum 2007), and Kenya (Beh and Bruyere 2007). However, our results show that these decisions exhibit a relatively high level of predictability. This suggests that once a more general model has been developed and tested, it may be simpler than expected to make predictions, from readily available data, about the potential future economic viability of individual protected areas and to explore their economic resilience under alternative models of infrastructural investment and visitor numbers.

Our results supported the notion that ecotourists are attracted by destination "pull factors" (Chan and Baum 2007), most often in the form of natural attractions and wildlife (e.g., Walpole and Leader-Williams 2002, Naidoo and Adamowicz 2005, Lindsey et al. 2007, Okello et al. 2008). In our study, ecological factors were represented by aesthetically valuable points of interest, water features, habitat diversity, and potential recreation and wildlife viewing opportunities, surface water features, species richness, and habitat diversity.

In accordance with studies that have shown water features to be a strong predictor of aesthetic preference (Dramstad et al. 2006, Han 2007) and rivers to be one of the main attractions to a protected area (Turpie and Joubert 2001), our broader results show that tourists appear to prefer national parks that have surface water and a diversity of ecological habitats and species. These examples illustrate how ecological variable may represent the "supply side" of cultural services. However, as our linear model results illustrate, the interaction between these "supply variables" may be complex, and trade-offs may exist between different uses of "ecological infrastructure". For example, our results show that although most measures of surface water influenced visitation rates in a positive way, the total number of inland water bodies negatively affected variation in visitors. This may be because many popular game species tend to be more dispersed and harder to see across landscapes in which surface water is plentiful. This result, together with the weaker performance of "recreation" within the ecological points of interest, points to a trade-off between providing recreational and aesthetic services and stocking potentially dangerous charismatic wildlife species (Reynolds and Braithwaite 2001). These trade-offs may explain why many of South Africa's national parks do not have significant infrastructure, such as trails providing access to ecological features, that would provide additional cultural services to visitors. The presence of dangerous species may also explain some of the differences in our results from those of studies done in Finland (Puustinen et al. 2009, Vanhatalo 2009, Neuvonen et al. 2010) and Costa Rica (Hearne and Salinas 2002), where a much stronger effect of recreational services was found. Trade-offs therefore occur between different kinds of cultural service, with potentially important implications for ecotourism in different locations.

Additionally, and perhaps more importantly, the linear models show individual ecological variables to be much weaker predictors of visitation rates than in models where they were are considered as a collective, and in combination with elements of location, infrastructure and affordability. This suggests that ecological variables are, by themselves, not sufficient to explain ecotourist visitation rates. The most visited national parks were those that combined ecological attractiveness with affordability and accessibility.

National parks are not all created and used equally. For example, in Finland, distance to population centers is an important determinant of park visitation numbers—but only in the south of the country (Puustinen et al. 2009, Neuvonen et al. 2010). In the north of the country, "fell parks", the mountainous areas that are considered to be aesthetically most remarkable, were, despite also being more remote, the most visited and longest stay parks in Finland (Puustinen et al. 2009, Neuvonen et al. 2010). Closer to population centers it is more important for parks to have well-developed infrastructure and recreational services, while visitation numbers to "resource-based" parks are unaffected by proximity, and thus require a slightly different management model (Puustinen et al. 2009). Puustinen et al. (2009) also showed that tourists visitation to water-based parks was more affected than other types of protected areas by recreational service provision, indicating that different types of visitor model might be needed for different kinds of protected area.

In our analysis, different factors were important in predicting overnight compared to day visitation rates, implying trade-offs in cultural service provision. In addition, the number of available units was a stronger predictor than "unit cost", even though camps with more accommodation were pricier. These findings suggest that an analogous situation to Finnish protected areas might exist in South Africa. From a practical management perspective, it appears that different kinds of park thus have different "optimal" business models, depending partially on the individual features of different areas and partially on infrastructural development. Business models for PAs will fall at different locations along axes of cost, visitor volumes, and differences between day and overnight visitors. For "resource-based" parks, at one extreme, a high-cost, low-volume, long-stay model would require extensive investment in accommodation and other overnight facilities, most likely including the expansion of the air travel network (as has occurred around Kruger NP), as well as the construction of new chalets, hotels, and restaurants. Although these parks may be situated "high and far", attributes that both affected variation in visitation rates negatively in our study, they may also be older, better known, and with a strong institutional history.

At the other extreme, a low-cost, high-volume, short-stay model (directed at day visitors) requires cheap access. This model will only work if the park is located near to existing airports and cities; and could be enhanced by the construction of infrastructure and offering access to ecological points of interest that will appeal to day visitors. For example, Tsitsikamma National Park lies on the N2 "Garden Route" around the South African coast and attracts significant numbers of visitors to a boardwalk that ends at a long, scenic suspension bridge.

In between these two models lies a wide range of opportunities for different compromises between features that appeal to short-stay and long-stay visitors, respectively. A further implication is that small differences in perceptions and infrastructure may have disproportionately large impacts on the number of visitors to individual national parks. For example, in Finland, Neuvonen et al. (2010) found that adding 10 km of trails to a National Park increased visitation rates by only 4%, while an increase in the opportunity for one or more recreational activities increased visitation rates by 30%.

National parks in South Africa are often ringed by private and provincial protected areas, many of which appear to cater to the same (or at least, substantially overlapping) market. Our analysis does not consider the interactions between different kinds of protected areas, so it remains unclear whether the close proximity of other kinds of protected area results in competition between areas for customers, has no effect, or leads to a general increase in overall visitation rates (as predicted under the shoe-shop or agglomeration effect; e.g., Baldwin and Okubo 2005). We would expect that adjacent private reserves and national parks are complementary, as shown for the U.S.'s park system (Henrickson and Johnson 2013), but the interaction between different PAs may be an important influence on occupation rates.

There are two additional considerations that must be taken into account when assessing our results. First, linear models have the disadvantage that they present a relatively static view of interactions and the ways in which systems change through time. Economies are built around scarcity and the relationships between supply and demand (Young 1982). As demand increases, neoclassical paradigms would predict that either supply or cost should increase. Affordability may thereby provide a strong predictor of perceived demand. Although feedback interactions might have produced the patterns that we see in the data, our analysis is correlative rather than mechanistic and hence does not directly take into account the dynamics of supply and demand. For instance, it is possible that internal transformation of an ecologically diverse national park in a relatively inaccessible area, such as Gorongoza National Park in Mozambique (Dondeyne et al. 2012), might create demand that in turn feeds back to provide greater funding for development, pushing the park along a trajectory of change.

Second, the failure of the time of year to emerge as an important variable in the analysis demands some explanation, given that tourism in South Africa has clear peaks and troughs defined by seasons and school holidays. We view the low predictive power of time as a consequence of the dominance of park location and size. Each camp and national park has a characteristic magnitude of visitors through the year, ranging from 5.75/month (±SD 0.80) (Kieliekrankie Camp, Kalahari

Gemsbok National Park) up to 14701.96/month (±SD 4362.94) (Crocodile Bridge camp, Kruger National Park). Although peaks and troughs in visitor numbers occur within each park, the magnitudes of visitors remain quite distinct; in Kruger NP, for example, the number of tourists visiting during the winter is an order of magnitude higher than in the Kalahari Gemsbok National Park. As our analysis compares between rather than within parks, it is driven by the overall differences in visitation rates rather than the finer scale variations in time.

In a similar vein, and in accordance with figures reported by SANParks in their annual reports, our results show no significant effect of the global financial recession on visitation rates. This result is in accordance with visitation figures reported in SANParks' annual report. Scholtz et al. (2013) conducted a survey to explore why tourists (both international and local) still visited national parks during a recession and found "push factors", such as escaping from stressful lives, to be a primary driving force. Additionally, they found that tourists adjusted their spending within parks to be able to finance their visit.

Ultimately, national parks cannot afford to lose sight of their primary mission of biodiversity conservation (Chape et al. 2003). This must be achieved within the context of economic fluctuations and within the confines of their responsibilities to the tax-paying public. In addition, national park viability must be built and maintained over long time horizons; the length of the period over which we require national parks to remain viable (i.e., >100 yr, or at least until human population pressure is low enough that formal parks are no longer necessary) means that every park is likely to experience one or more social, ecological, and/or economic perturbations during its lifetime. We have considered parks as providers of cultural ecosystem services; our analysis shows clearly that the experience of those services by the public is a function not only of biodiversity within the park itself but also (and to a relatively high degree) of a set of access-related variables such as infrastructure and cost. Implicit in our analysis is the idea that the best strategy for achieving long-term sustainability will be to diversify the business models by which national parks are run, tailoring approaches in each case to optimize economic returns under the set of ecological and location "givens," while connecting revenue streams between different national parks and partnering with private and provincial parks to provide a greater range of options for adaptation and innovation.

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