Using multivariate statistics to assess ecotourism potential of water-bodies: a case-study in Mauritania

Abstract

Evaluating the ecotourism potential of sites is a key issue in tourism management. Multiple methodologies have been developed to assess the ecotourism potential of sites. However, there are many constraints affecting their quality. Methodologies independent of subjective criteria and weights are lacking, compromising following interpretations on where to allocate efforts for ecotourism development. We propose a new approach to circumvent these issues that combines independent statistical procedures to assess ecotourism potential. By combining multi-criteria with ordination and clustering algorithms, this two-stage statistical approach allowed identifying suitable water-bodies for ecotourism development in Mauritania and independently assessed which features are related with ecotourism potential. The method was able to group sites for different ecotourist demands, which has implications for policy makers and tourism planners trying to optimize investments while protecting biodiversity and supporting communities. We provide a framework that is scalable and applicable by stakeholders operating in ecotourism planning and management worldwide.

Keywords: tourism planning; deserts; multi-criteria approach; ordination methods; clustering algorithms; low-income countries; wetlands.

1. Introduction

Ecotourism is considered an efficient tool for biodiversity conservation (Fennell, 2015; Lindsey, Alexander, du Toit, & Mills, 2005; Mossaz, Buckley, & Castley, 2015; Penteriani et al., 2017). It helps building environmental awareness among ecotourists and local communities (Honey, 2008; Reimer & Walter, 2013) and can fund effectively conservation initiatives (Kirkby et al., 2010, 2011), resulting in several positive net-effects of environmental outcomes (see Bricker & Kerstetter, 2017; Buckley, 2009; Weaver, 2002). Ecotourism may be a potential tool for the reduction of poverty in low-income countries (Goal 1 of the United Nations Sustainable Development Goals) and the sustainable economic development of poor communities with decent employment for all (Goal 8; <http://www.un.org/sustainabledevelopment/sustainable-development-goals/>; see Reimer & Walter, 2013; Saarinen & Rogerson, 2013; Scheyvens, 1999). Despite potential negative impacts, such as marginalization of local communities and species habituation to human presence (see Penteriani et al., 2017; Weaver, 2002), ecotourism is widely being promoted as a strategy that fosters beneficial relationships between tourism, the environment and local communities living in low-income countries, especially in Africa (Lindsey et al., 2005; United Nations, 2017). The potential of ecotourism in contributing to poverty alleviation and threatened species preservation has been claimed for African deserts (Santarém & Paiva, 2015; Weaver, 2001), particularly for the Sahara-Sahel ecoregions (Brito et al., 2014, 2016). All countries in the region are low-income nations, most of them exhibiting low human development index (UNDP, 2016). Historically, they have been underfunded for poverty alleviation and biodiversity loss retention schemes (Durant et al., 2012; Waldron et al., 2013). Mauritania is one of these African arid countries, where around 40% of people live in rural areas, lacking both infrastructural and health conditions (FAO, 2013). The country displays multiple cultural, biological and landscape values that may be suitable for sustaining ecotourism projects (Vale, Pimm, & Brito, 2015). Mauritanian water-bodies are of particularly relevance, as they are rich in human heritage and biodiversity. On the one hand, they may be surrounded by well-preserved villages where traditional livelihoods and secular ceremonies still occur. There are ancient wells for cattle watering, evidences of intense intellectual activity propagated by caravans crossing the *ksours* (Mauritanian towns) since the Middle Ages, and archaeological remains in the form of rock-paintings (Hosni, 2000; UNESCO, 2003). On the other hand, water-bodies may hold up to 78% of the endemic fishes, amphibians, reptiles and mammals of Mauritania (Vale et al. 2015). They gather large concentrations of water-birds (Cooper, Shine, McCann, & Tidane, 2006), that provide bird-watching opportunities. The surrounding habitats, where dunes intersect with unique desert-adapted agricultural patches (oasis), and the presence of geological formations (waterfalls) on rock canyons are of great interest for ecotourism. In addition, several water-bodies contain relict West African crocodile populations (Brito, Martínez-Freiría, Sierra, Sillero, & Tarroso, 2011) that have been considered as a national flagship species (Telleria, Ghaillani, Fernandez-Palacios, Bartolome, & Montiano, 2008), which help marketing the species and its habitats to conservation and ecotourism programmes (Veríssimo et al., 2013, 2014). Based on these, the potential for ecotourism development in the desert water-bodies of Mauritania is promising, but requires urgent assessment and research-informed planning, given the local societal development and biodiversity conservation needs. One potential caveat to developing such assessments in these regions is related to the lack of

a systematic approach to evaluate the ecotourism potential of sites with knowledge-based and well-informed criteria for ecotourism planning. This paper proposes a new method that aims to go beyond subjective criteria and weights in ecotourism site planning by combining independent statistical procedures to assess ecotourism potential. By combining multi-criteria with ordination and clustering algorithms, this two-stage statistical approach is used here for identifying suitable water-bodies for ecotourism development and for assessing independently which features are related with ecotourism potential. The follows this organization: Approaches to evaluate ecotourism potential, where we introduce methods that have been used in ecotourism potential assessments, their caveats and theoretical methodological solutions; Methods, where we characterize the study area, detail how we combine two independently-used statistical methods how to analyse the data; Results, where we present the contribution of the variables for the ecotourism potential of the water-bodies under study, their grouping according to different ecotourist demands, and their suitability for developing ecotourism activities; Discussion, where we establish the improvements of this method towards previous ones, the methodological aspects in need of further research, factors that are relevant to consider for developing ecotourism in water-bodies, and traits of suitable water-bodies for different ecotourist demands; and Conclusion, where we present a summary of the improvements and potentials of using the method here purposed.

2. Approaches to evaluate ecotourism potential

Ecotourism is a relatively new concept in tourism planning but its basic elements and dimensions have been discussed for decades in studies on tourism and natural resource management (Fennell, 2015; Honey, 2008; Stronza, 2007; Weaver, 2001). There are numerous definitions for ecotourism (see Donohoe & Needham, 2006). In general, it refers to responsible travel to natural areas with an aim to use tourism demand for conservation goals, environmental education and local communities benefits (Diamantis, 1999; Fennell, 2001; Weaver, 2001). There is a strong focus on sustainable tourism development with an emphasis on ecologically sound and driven practices (Saarinen, 2006). Therefore, comprehensive biodiversity evaluations and assessments are often included to ecotourism planning. In this context, multi-criteria approaches combining ecological and social data, and spatial analyses conducted in Geographical Information System (GIS) environments have been integrated to assess the ecotourism potential of many sites around the globe.

The multi-spatial layers and the continuous analyses allowed by GIS tools increase the spatial accuracy of predictions and the information handled, thus assisting in the decision-making process (Dhami, Deng, Burns, & Pierskalla, 2014; Dhami, Deng, Strager, & Conley, 2017). For instance, GIS and participatory methods (Delphi and Analytic Hierarchy Process, AHP) were used to map ecotourism as a cultural service (Nahuelhual et al., 2013), high resolution IKONOS images and GIS were used for planning useful resources to ecotourism (Fung & Wong, 2007), and visitor's preferences were assessed for mapping weighted and unweighted potential sites for forest-based ecotourism development (Dhami et al., 2014).

Despite the plethora of methods being proposed for assessing cultural ecosystem services (where ecotourism is included), there are still constraints affecting the quality of those assessments. Most studies rely on a priori controlled approaches that require weighting of variables, either via inquiries or expert-knowledge scoring. While they are often practical, such approaches have also been criticized (Kliskey, 2000), and methods

that are independent of subjective criteria and weights are still lacking (Milcu, Hanspach, Abson, & Fischer, 2013).

Circumventing a priori classification approaches requires independent methods that assess the contribution of variables without necessarily weighting them, such as ordination methods and clustering algorithms. Principal Component Analysis (PCA) is a statistical procedure that uses orthogonal transformations to convert observations of possible correlated variables into linearly uncorrelated variables, which emphasizes variation and brings out relevant patterns in a dataset (Hotelling, 1933). PCA produces a series of orthogonal uncorrelated axes, where the first component accounts the largest possible variability in the data and the following components account for decreasing proportions of the variability. Cluster analysis is an unsupervised learning task in data mining that consists in grouping a set of objects in a way that objects in the same group (called a cluster) are more similar to each other than to those in other groups (Tryon, 1939). Both statistical approaches have been applied independently in tourism research. For instance, PCA was used to assess social preferences for recreation demands in a three-stage procedure for mapping recreation potential (Peña et al. 2015) and to identify suitable variables associated to the implementation of recreation activities (Kliskey 2000), while cluster analysis was used to identify distinct groups of adventure travellers (Sung 2004).

The advantage of using PCA is that it allows the empirical quantification of the influence of biological, ecological and human-related variables in the suitability of a site for ecotourism development. Cluster analysis allows to group sites sharing similar characteristics, which can help managing distinct groups of ecotourists with particular demands. When used jointly with ordination methods, the two-stage multivariate statistics approach improves interpretations in tourism studies (Arimond & Elfessi, 2001; Pina & Delfa, 2005). The application of multivariate statistics to assess suitable sites for recreation development has been emphasised by some authors (e.g. Kliskey 2000), but the use of ordination methods and clustering algorithms for pairwise grouping remains unexplored in ecotourism research (Weaver, 2001). This combination of statistical methods might help elucidating where to allocate efforts to meet different ecotourists demands, especially in regions offering conditions to attend both ‘hard’ (environmentally specialized, physically challenging, minimally commodities serviced, strongly biocentric) and ‘soft’ (shallow interaction with nature, physically passive, comfort demanding, heavily commodities serviced, shallow interaction with nature) ecotourist profile needs (Fennell & Weaver, 2005; Weaver, 2001, 2002).

Here, we combine for the first time a PCA with a clustering algorithm to identify suitable locations for ecotourism development. We explore approaches based in multi-criteria coupled with ordination and clustering algorithms that are independent from a priori weighting. Specifically, we want to address the following questions: 1) Which variables contribute the most to explain the variability of water-bodies to ecotourism development?; 2) How many groups of water-bodies can be distinguished according to their characteristics for ecotourism potential?; and 3) Which groups of water-bodies display characteristics associated with potential for ecotourism development? We aim to demonstrate that the methodological process is suitable to characterize the ecotourism potential of regions with recreation appeal that lack conservation and development funding, and that it can be scalable and replicable worldwide.

3. Methods

3.1. Study area

Mauritania is located between 15.8°N and 20.6°N and west of 9.5°W. Climate is characterized by a dry, cool season approximately from November to February and a dry, hot season approximately from March to June. Annual rains are scarce and seasonal, with most precipitation occurring between August and September (Cooper et al., 2006). The country has a poor road system and key infrastructures are almost only available in main cities (WEF, 2017).

The methodological process was applied to a set of 30 water-bodies dispersed throughout the southern mountains of Tagant, Assaba and Afollé (Figure 1). These water-bodies display distinct characteristics in topography, altitude, landscapes, and other environmental and anthropogenic features, comprising gueltas (rock-pools in mountainous canyons), tâmoûrts (seasonal floodplains located on the foothills of the mountains), sources, lakes, and oueds (rivers; see details about water-bodies definitions in Brito et al., 2011). The water-bodies were visited by four researchers during 22 days in January 2016. The coordinates of water-bodies were gathered from a Global Positioning System (GPS) and were displayed in ArcGIS 10.1 (WGS84 datum).

Figure 1. Location of the 30 water-bodies studied (and code number), main settlements with supporting infrastructures (and their names), paved roads, rivers, and mountains. The location of the capital (Nouakchott) is depicted in the small inset.

3.2. The multi-criteria approach

A total of 16 variables were selected for analyses, including two variables related to the biological interest of water-bodies, nine variables describing their environmental traits, and four variables depicting human activities and infra-structures associated to them (Table 1).

199 Table 1. Types of variables used to assess the ecotourism potential of water-bodies, their codes, description, interest for ecotourism (Min-minimum and Max-
200 maximum), units, and source.

Type	Code	Description	Interest	Units	Source
Biological	CR	Maximum number of crocodiles reported	Max	Number	Brito et al. 2011; Campos et al. 2016
	BI	Bird species richness index	Max	Number	Fieldwork
Environmental	AREA	Surface area	Max	m ²	Fieldwork
	SL	Topographic heterogeneity	Max	Degrees	SRTM 90m Digital Elevation Database v4.1 (http://www.cgiar-csi.org)
	WA	Water availability	Max	Adimensional	Campos et al. 2012
	NDVI	Vegetation Productivity	Max	Adimensional	LP DAAC (http://lpdaac.usgs.gov)
	NWB	Euclidian distance to the nearest water-body	Min	Meters	Fieldwork and GIS analysis
	WBH	Habitat heterogeneity	Max	Number	PostelMedias: GLOBCOVER 2006 (http://postel.obs-mip.fr)
	RH	Habitat heterogeneity from the nearest paved road	Max	Number	PostelMedias: GLOBCOVER 2006 (http://postel.obs-mip.fr)
	DA	Area covered by dunes	Max	m ²	PostelMedias: GLOBCOVER 2006 (http://postel.obs-mip.fr)
	AA	Area covered by agricultural land	Max	m ²	PostelMedias: GLOBCOVER 2006 (http://postel.obs-mip.fr)
	MTW M	Maximum temperature of the warmest month	Min	°C	Worldclim (http://www.worldclim.org)
Anthropogenic	DR	Distance to the nearest paved road	Min	Meters	Fieldwork and GIS analysis
	DI	Distance to the nearest settlement with supporting infrastructures	Min	Meters	Fieldwork and GIS analysis
	IUCN	Number of IUCN threat factors categories	Min	Number	Campos et al. 2016
	HII	Human influence index	Min	Adimensional	SEDAC (http://sedac.ciesin.columbia.edu)

The 16 variables were selected based on established relationships with the ecotourism potential of the water-bodies to attract international tourists (Table 1). Flagship species are considered key for ecotourism development (Veríssimo, Fraser, Groombridge, Bristol, & MacMillan, 2009; Walpole & Leader-Williams, 2002). Thus, we selected widely accepted flagship species, such as crocodiles (Telleria et al., 2008) and birds (Veríssimo et al., 2009). The 30 water-bodies were sampled to record the maximum number of individual West African crocodiles (*Crocodylus suchus*) and the number of different bird species. The sampling effort was on average 0.273 man/hours in each water-body. Estimations of crocodile numbers followed standard sampling protocols (Brito et al., 2011; Campos, Martínez-Freiría, Sousa, Santarém, & Brito, 2016). In water-bodies where crocodiles were not detected in January 2016, but were known to occur, the number of estimates were based in previous reports (Brito et al., 2011). The number of bird species in each water-body was accessed by point sampling, using binoculars and telescopes. Species identification was based in field-guides (Borrow & Demey, 2001). The number of observed species was weighted by the sampling effort in each water-body (in minutes) to obtain an index of bird species richness that considers temporal biases in sampling efforts and allows sites to be compared.

Environmental features, such as high slopes may influence ecotourism potential of a site (Dhami et al., 2014, 2017), and we measured it by calculating the standard deviation of the slope (derived from altitude at 90m resolution) in 1x1km window around each water-body, using the “Buffers” tool of ArcGIS 10.1 (ESRI, 2012). Water-bodies with large areas and permanent water availability play a crucial role in desert environments, allowing the observation of large species diversity and traditional human activities, such as water pumping from mudbrick-wells for watering cattle (Brito et al., 2014, 2016; Hosni, 2000; Vale et al., 2015). Thus, the area of each water-body was estimated in the field with a GPS and the water availability was assessed using the Normalized Difference Water Index (NDWI) at 1 arc second resolution in a 1x1km window around water-bodies. Vegetation heterogeneity is well appreciated by tourists (Chhetri & Arrowsmith, 2008; Dhami et al., 2014, 2017) and thus, we used the Normalized Difference Vegetation Index (NDVI) time-series from the period between 2000 and 2016, at 250m resolution to extract it in a 1x1km window around water-bodies. Short geographic distances between visiting sites are best acknowledged because tourists and ecotourism enterprises tend to maximize, in general, the return on time/money invested to visit a region (Kienast, Degenhardt, Weilenmann, Wäger, & Buchecker, 2012). Thus, we calculated the Euclidean distances between water-bodies. High habitat heterogeneity influences a site appraisal for ecotourism (Nahuelhual et al., 2013; Santarém, Silva, & Santos, 2015). Thus, we recorded the habitat heterogeneity around water-bodies and from the nearest paved road to the water-bodies, using a 1x1km window around water-bodies. In desert environments, the observation of dunes adds an increased experience to the observer (Cooper et al., 2006; Hosni, 2000). We calculated the area covered by dunes in a 1x1km window surrounding the water-bodies based on land-cover classification by remote sensing. Local agriculture is mostly based in ancient practices that may add value to the aesthetic visit of water-bodies (Chan, Shaw, Cameron, Underwood, & Daily, 2006). Thus, we calculated the area covered by agricultural patches in a 1x1km window surrounding water-bodies. Weather conditions can influence recreation opportunities and in remote regions they are of great concern for the well-being of tourists (Kienast et al., 2012). Thus, we extracted the maximum temperature of the warmest month in a 1x1km window surrounding the water-bodies. Anthropogenic factors, such as the time to access a touristic point or a settlement with supporting infrastructures, may be crucial for tourism activities (Castro, Souza, &

Thapa, 2015; Kienast et al., 2012). Time to get to a visiting site is greatly influenced by the distance and the road type (Chan et al., 2006; Paracchini et al., 2014; Wong & Fung, 2015). Thus, we measured the distance from the water-bodies to the nearest settlement with supporting infrastructures (hospitals, restaurants or accommodation resources; Chhetri & Arrowsmith, 2008). As most of the water-bodies are far from the main paved roads (see Figure 1), we also measured the distance from the water-bodies to the nearest paved road (Dhami et al., 2014). Both distances were recorded using a GPS. Anthropogenic impacts on environment are global drivers of ecological processes that influence biodiversity as a whole (Sanderson et al., 2002) and affect biodiversity availability for tourism experiences in the field. The number of threats affecting the water-bodies was quantified following the IUCN Threats Classification Scheme Version 3.2 (www.iucnredlist.org/technicaldocuments/classification-schemes/threats-classificationscheme) and was available from Campos et al. (2016). The Human Influence Index (HII) was extracted in a 1x1km window around each water-body.

3.3. Data analysis

We used a PCA to identify which variables contribute the most to explain the variability of water-bodies for ecotourism development. To do so, we scaled data by subtracting each variable value by its mean and then dividing by its standard deviation. This process converted each raw datum score into a standardized value with mean 0 and standard deviation 1. We then plotted water-bodies along the two first principal components to identify main patterns of clustering of water-bodies.

Groups of water-bodies sharing similar biological, environmental and anthropogenic characteristics for ecotourism were identified using a model-based clustering approach. Ten multivariate normal mixture models with different parameterizations concerning the distribution, volume, shape and orientation of the covariance structure of the multivariate data of the water-bodies were estimated by maximum likelihood using an expectation-maximization algorithm. The best model and the most likely number of clusters were chosen using the Bayesian Information Criterion (BIC). Analyses were performed using the three first, most explaining, principal components to assess the number of optimum clusters. Finally, we contrasted the distribution of the groups identified by the clustering algorithm with the variables represented in the first and second principal component (PC1 and PC2, respectively) axes. This process allowed identifying groups of water-bodies suitable for different sets of ecotourists, ‘hard’ and ‘soft’ (Fennell & Weaver, 2005; Weaver, 2001, 2002). Both the PCA and the clustering analysis were performed in R environment (R Core Team, 2016) with the *mclust* package (Fraley & Raftery, 2002; Fraley, Raftery, Murphy, & Scrucca, 2012).

4. Results

4.1. Contribution of variables to the variability of water-bodies for ecotourism development

The variables with the highest influence in the first, second and third axes of the PCA were: water availability (WA) and maximum temperature of the warmest month (MTWM) in the first axis; vegetation productivity (NDVI) and distance the nearest settlement with supporting infrastructures (DI) in the second axis; and distance to the nearest paved road (DR) and habitat heterogeneity from the nearest paved road to water-bodies (RH) in the third axis (Table 2). The two first axes accounted for 38% of the

variability. The representation of water-bodies along the two first axes allowed identifying three groups of water-bodies for ecotourism development (Figure 2).

4.2. Grouping of water-bodies according to ecotourism potential

We used the model with the highest BIC (spherical, equal volume with seven components, “EII”; Figure S1) to group water-bodies according to their most similar characteristics for ecotourism. The BIC increased with the number of clusters and most of the increase occurred with less than seven clusters, which were chosen as the optimum number of clusters defining the groups for ecotourism development. These seven subgroups of water-bodies fall inside the three main groups of water-bodies identified by the PCA (Figure 2).

4.3. Suitability of water-bodies for ecotourism development

The green group defined by the PCA contained three subgroups of water-bodies defined by the clustering algorithm (Figure 2) that, in comparison to other groups, tended to display more flagship species (larger crocodile populations, more bird species), higher habitat heterogeneity around the water-body, higher water availability, larger flat surface areas, shorter distances between each other, wider agriculture areas in the surroundings, and the highest human impacts (Table S1; Figures 3-S2). The blue PCA group gathered water-bodies that tended to exhibit the highest topographic heterogeneity and habitat heterogeneity along the roads to reach water-bodies, the highest temperatures in the warmest month, the largest distances to paved roads and cities with supporting infra-structures, the lowest productivity, and the fewer number of IUCN threats (Table S1; Figures 3-S2). The red PCA group contained three BIC subgroups of water-bodies that tended to display the highest topographic heterogeneity, the fewer number of flagship species, and the smallest areas and water availability. Within this group, there is a subgroup (dark red squares) of water-bodies that recorded numerous IUCN threat factors and are far from paved roads and infrastructures (Table S1; Figures 3-S2).

Overall, there is a trend for lack of geographic structure in the distribution of the groups, but the main blue group (Figure 2) is restricted to the northernmost water-bodies of the Tagant mountain and subgroup A2 is restricted to the eastern Afollé mountain (Figure 3).

336
337

Table 2. Eigenvalues of each variable in each principal component, and the standard deviation (SD) and cumulative variance (CUM) of the principal components.

Variable	<i>PC1</i>	<i>PC2</i>	<i>PC3</i>	<i>PC4</i>	<i>PC5</i>	<i>PC6</i>	<i>PC7</i>	<i>PC8</i>	<i>PC9</i>	<i>PC10</i>	<i>PC11</i>	<i>PC12</i>	<i>PC13</i>	<i>PC14</i>	<i>PC15</i>	<i>PC16</i>
CR	-0.166	-0.061	0.039	0.631	-0.227	-0.043	0.129	-0.043	-0.279	-0.052	0.502	-0.231	-0.246	0.144	-0.160	0.059
BI	-0.314	-0.184	-0.013	-0.115	-0.250	-0.116	0.398	-0.604	0.158	-0.250	-0.059	0.310	-0.020	-0.198	-0.122	0.118
AREA	-0.291	-0.073	0.193	-0.295	-0.184	-0.377	0.177	0.562	-0.139	-0.025	0.068	0.108	0.144	-0.010	-0.418	-0.176
SL	0.254	0.215	0.124	0.011	0.508	-0.283	0.331	-0.207	0.184	-0.076	-0.088	-0.245	-0.130	0.282	-0.406	-0.120
WA	-0.458	0.093	-0.060	-0.210	0.142	0.059	0.146	-0.157	-0.016	0.177	0.150	-0.634	0.273	-0.225	0.201	-0.208
NDVI	0.050	-0.493	0.200	-0.137	-0.088	-0.029	0.033	0.098	0.004	0.133	-0.346	-0.416	-0.526	-0.168	-0.004	0.248
NWB	-0.312	-0.057	0.224	-0.249	0.193	0.350	-0.433	-0.061	0.101	-0.429	0.206	0.026	-0.328	0.143	-0.154	-0.218
WBH	-0.190	-0.211	-0.048	0.111	0.500	0.304	0.383	0.232	-0.369	-0.283	-0.166	0.131	0.129	0.058	0.132	0.250
RH	-0.136	0.204	-0.484	0.121	-0.115	-0.079	-0.193	-0.072	-0.388	-0.204	-0.524	-0.110	-0.150	-0.078	-0.212	-0.277
AA	-0.354	-0.137	0.201	0.295	0.095	0.233	-0.120	-0.119	0.100	0.587	-0.308	0.183	0.134	0.192	-0.294	-0.104
DA	-0.176	-0.082	-0.432	0.035	0.422	-0.259	-0.044	0.110	0.144	0.283	0.264	0.284	-0.396	-0.323	0.032	-0.045
MTWM	-0.411	0.272	-0.139	-0.083	-0.108	-0.228	0.006	0.111	0.211	0.009	-0.138	-0.028	-0.182	0.581	0.316	0.346
DR	0.043	-0.320	-0.498	-0.060	-0.003	0.083	-0.203	0.036	0.254	-0.090	0.125	-0.223	0.334	0.123	-0.434	0.377
DI	0.134	-0.456	-0.291	-0.054	-0.140	0.100	0.273	0.039	0.118	0.020	0.029	0.017	-0.051	0.413	0.219	-0.587
IUCN	0.033	-0.329	0.092	-0.178	0.187	-0.456	-0.337	-0.348	-0.496	0.088	0.092	0.053	0.161	0.248	0.136	0.053
HII	-0.121	-0.228	0.169	0.465	0.113	-0.372	-0.212	0.121	0.383	-0.364	-0.193	-0.082	0.236	-0.159	0.225	-0.153
SD	1.771	1.670	1.468	1.250	1.143	1.028	0.876	0.833	0.741	0.648	0.590	0.495	0.423	0.395	0.267	0.166
CUM	0.203	0.383	0.523	0.624	0.708	0.776	0.826	0.871	0.906	0.934	0.956	0.972	0.984	0.994	0.998	1.000

Figure 2. Water-bodies grouped according to the three first components of the Principal Component Analysis (PCA) and Bayesian Information Criterion (BIC). The seven subgroups (blue triangles; dark green, green and light green circles; dark red, red and orange squares) identified by the BIC clustering are within the three groups (blue, green and red hulls) identified by the PCA.

Figure 3. Distribution of the three groups identified by the Principal Component Analysis (PCA; squares, circles and triangles) and of the seven subgroups identified by the Bayesian Information Criterion (BIC) models (different colours of squares, circles and triangles). See Table S1 for grouping details and Figure S2 for grouping examples.

5. Discussion

By combining ordination and clustering algorithms, we could identify sites for ecotourism development in a systematic way, by emphasizing strong patterns across different groups of water-bodies. The method allowed evaluating independently which variables contributed the most for the definition of ecotourism potential of each site. To our knowledge, this is the first study doing that. The methodology here presented has important implications for decision-making in ecotourism planning and can help stakeholders identifying the best sites for local investment. This two-step approach can be scalable and replicable to other regions where ecotourism interest is growing, and where proper consultation and management are needed to avoid further impacts. We propose a set of improvements to be considered if this methodology is to be applied in the future.

5.1. Methodological improvements from previous approaches

The methodology proposed herein improved the identification of suitable sites for ecotourism. The main advantage of this method in detriment to previous approaches is the combination of ordination (PCA) and clustering algorithms (BIC) in a non-heuristic way. The ordination method allowed assessing the contribution of variables without requiring expert knowledge, which otherwise could compromise following interpretations due to subjectivity of people's choices (Milcu et al., 2013). The cluster analysis allowed grouping sites sharing similar characteristics for ecotourism, which can help managing distinct groups of ecotourists with particular demands. Also, by

estimating the parameters of the mixture models with empirical data, the choice of optimum number of clusters was a statistical decision, rather than an intuitive judgment. This approach avoided choosing the optimum number of clusters heuristically, as in non-model-based approaches (Fraley & Raftery, 2002). This approach assessed the contribution of variables without necessarily weighting them before further analyses, thus circumventing *a priori* classification schemes. To our knowledge, this was the first study combining ordination methods and clustering algorithms for pairwise grouping in ecotourism research, which addresses previous criticisms on dependent methods relying on subjective criteria and expert-knowledge scoring (Kliskey, 2000). This process avoids misleading interpretations, thus maximizing the investment planning towards the places suitable for ecotourism development. The multi-criteria approach here used constitutes further strength of the methodology. It relied on key biological, environmental and anthropogenic features to assess the ecotourism potential of water-bodies. This approach considers both the ecotourism attraction capacity, i.e. the natural features of the territory, and the demand side, i.e. the conditions that influence the tourism attraction capacity of the sites. The combination of both sets of attributes is crucial for ecotourism assessments and remained under-explored to date (Nahuelhual et al., 2013).

5.2. Methodological aspects needing further research

Despite this two-stage multivariate statistics approach allowed circumventing previous caveats in tourism studies, some methodological improvements shall be considered to refine its application. In this study, only continuous variables were considered for the PCA input. However, assessments of ecotourism potential often compile categorical variables, which may be beneficial to characterise the suitability of sites. Statistics such as Principal Coordinates Analysis (PCoA), allow exploring data dissimilarities and can analyse jointly categorical and continuous variables. This multidimensional scaling method starts with a dissimilarity matrix (distance matrix) and assigns for each entry in the matrix a location in a low-dimensional space. PCoA tries to find the main axes through a matrix and calculates a series of eigenvalues and eigenvectors, in a similar way as PCA does (Pavoine, Dufour, & Chessel, 2004). For instance, PCoA has been explored for pairwise grouping of Sahara-Sahel endemic species (Vale & Brito, 2015). Its potential for tourism studies remains unexplored.

The multi-criteria approach here used considered an array of distinct variables related to ecotourism potential of the water-bodies. They were suitable for the scale of the sites under analysis (isolated points in space), but ecotourism potential assessments can consider other variables that are dependent on continuous scales. For instance, other animal groups could also be included in the analyses, after evaluating which flagship species may appeal to broader audiences (Veríssimo et al., 2009; Veríssimo, MacMillan, & Smith, 2011). When performing analysis at broader scales, other biological groups may also be considered (Santarém et al., 2015). For instance, southern Mauritania concentrates the largest proportion of species richness of the country (Brito et al., 2016), and thus water-bodies located in these regions might be of special interest for ecotourists. The economic welfare of water-bodies nearest villages and the local willingness of villagers for ecotourism investments should be also considered in assessments (Castro et al., 2015), as investment priority should be given to those communities with fewer resources. Furthermore, increasing the representativeness of

sampling may result in better performance of the model-based clustering algorithm, which may elucidate where to allocate efforts for ecotourism implementation.

5.3. Factors relevant for assessing suitability of desert water-bodies for ecotourism

The multi-statistics approach here used allowed the identification of key variables to assess ecotourism potential of desert water-bodies, such as water availability. Duration of standing water was previously found to be key for wildlife in desert contexts (Cooper et al., 2006), and greater areas with permanent water usually concentrate more species that appeal to the ecotourist, especially endemic species with high flagship potential (Vale et al., 2015). Particularly, they aggregate flocks of birds, highly appreciated by ecotourists and birdwatchers worldwide (Veríssimo et al., 2009; Veríssimo et al., 2014) that are frequently willing to spend considerable amounts of money to spot these flagship species (Steven, Castley, & Buckley, 2013). Thus, water availability should be considered in future assessments of ecotourism potential of water-bodies.

Maximum temperature of the warmest month and vegetation were also identified as being associated with suitability of water-bodies to ecotourism. Despite high temperatures in the peak of the hot season were not found to be relevant for recreation in temperate environments (Switzerland; Kienast et al., 2012), they may be considered in ecotourism activities in desert environments (e.g. in Mauritania). Likewise, vegetation is known to be an influencing factor for ecotourism development in non-desert biomes (Dhami et al., 2014, 2017) and a key predictor of scenic attractiveness in an Australian region with savannahs and shrub lands (Chhetri & Arrowsmith, 2008), supporting its consideration in recreation and ecotourism potential assessments in all biomes.

The potential observation of multiple habitats along the roads leading to the recreational sites was identified as influencing the ecotourism potential of water-bodies. This observation is supported by previous studies that found the number of different habitats in a line-transect influencing landscape appeal (Santarém et al., 2015). Particularly, agricultural patches around desert water-bodies add an increased value to the ecotourist. As ancient practices of agriculture in arid environments are reflected around these water-bodies (Cooper et al., 2006), agricultural land should be considered when assessing the potential of desert water-bodies for ecotourism development.

The methodology explored herein found both distance-related variables (to roads and infra-structures) to be associated to the ecotourism potential of a site, which is particularly relevant for desert contexts (Weaver, 2001). Remoteness was recently found to be one of the most important criteria for ecotourism development for both visitors and ecotourism-experts (Dhami et al., 2017). Though Paracchini et al. (2014) found a positive correlation between remoteness level and recreation opportunity in Europe, in desert contexts, such as the Sahara-Sahel, characterised by poor road systems and hostile weather/environments (WEF, 2017), planners may wish to consider distance as a pivotal constrain to ecotourism development. Intermediate levels of distances to roads and supporting infrastructures can be considered, depending on ecotourists demands and territorial contexts (Nahuelhual et al., 2013).

5.4 Traits of suitable water-bodies for ecotourism development

The PCA discriminated three core groups of water-bodies with distinct traits that may be suitable for ecotourists with different demands. This has implications for ecotourism planners that want to maximize return-on-investment and that need to consider the

demands of distinct hard- and soft-types of ecotourists (Weaver, 2001, 2005). One group of water-bodies (green hull; Figures 2-3) exhibits several characteristics that may be ideal for the soft-ecotourist, which usually demands short trips with physical comfort and nearby services, and has moderate environmental commitment (Weaver, 2001, 2005). These water-bodies are in proximity to cities with supporting infrastructures and display large water-surface areas with high water availability, where flagship species concentrate.

The northernmost group of water-bodies (blue hull; Figures 2-3) recorded the highest air temperatures and topographic variations, and thus may be challenging to visit by the most common ecotourist. These water-bodies are apparently suitable for “hard-desert” ecotourists trying to obtain the highest return from the desert natural landscapes visited. Hard-ecotourists are usually looking for physical challenging environments, travel in small and specialized groups to regions with few if any services available, and have strong environmental commitment (Weaver, 2001, 2005).

The third group of water-bodies (red hull; Figures 2-3) displays characteristics that are apparently less suitable for ecotourism development. These include low water-availability, low agricultural and dunes-covered lands, and low number of flagship species, alongside the long distances from roads and supporting infrastructures. These water-bodies exhibit numerous IUCN threats, which may have implications for both biodiversity and ecotourists pursuing natural experiences in deserts. From the ten water-bodies identified as biodiversity hotspots by Vale et al. (2015), we have here accessed half of them, and four out of these five water-bodies were identified to be less suitable for ecotourism development. The water-bodies within this group should be prioritized for reducing current threat levels before considering them for ecotourism development.

6. Conclusions

In addition to local support and benefit creation, ecotourism is highly dependent on natural areas, their biodiversity and the Human communities depending on their natural resources. Therefore, sophisticated approaches in the assessment and mapping of ecological environment are constantly needed in ecotourism planning. Here, a two-stage multivariate statistic was developed, which allowed grouping water-bodies according to their different characteristics for ecotourism development. Such grouping has implications for ecotourism planners and academics that need to tailor tourist visits according to the profiles of different ecotourists. As ecotourism planners may face different demands from distinct ecotourist types, this methodology helps maximizing return-on-investments and enhancing local economies. However, as these biodiversity rich sites often involve intrinsic cultural heritage values and local livelihoods there needs to be also careful ethical considerations involved with ecotourism developments and related research. The developed and proposed approach does not indicate where we should but where we could place tourism activities in an optimal situation.

Thus, any approach to develop ecotourism in these water-bodies needs to be further contextualized and underline their specificities, as emphasised in this paper, to not deteriorate these fragile socio-ecological systems in touristic uses. By adding ecological and anthropogenic variables to biological data of water-bodies, the methodology presented here can provide a basic information where to optimally allocate investments for wildlife conservation and local development, while meeting different ecotourist demands. This is especially relevant in low-income countries and poor peripheral regions with high tourism potential that lack economic resources and conservation and

523 ecotourism investments. In this respect, policy makers might use the framework here
524 provided to achieve the United Nations Sustainable Goals, particularly in what respect
525 combating poverty while protecting biodiversity and key ecosystem services.

References

- Arimond, G., & Elfessi, A. (2001). A clustering method for categorical data in tourism market segmentation research. *Journal of Travel Research*, 39(4), 391–397. <https://doi.org/10.1177/004728750103900405>
- Borrow, N., & Demey, R. (2001). *Birds of Western Africa*. London: Christopher Helm.
- Brito, J. C., Godinho, R., Martínez-Freiría, F., Pleguezuelos, J. M., Rebelo, H., Santos, X., ... Carranza, S. (2014). Unravelling biodiversity, evolution and threats to conservation in the Sahara-Sahel. *Biological Reviews*, 89(1), 215–231. <https://doi.org/10.1111/brv.12049>
- Brito, J. C., Martínez-Freiría, F., Sierra, P., Sillero, N., & Tarroso, P. (2011). Crocodiles in the Sahara desert: An update of distribution, habitats and population status for conservation planning in Mauritania. *PLoS ONE*, 6(2), e14734. <https://doi.org/10.1371/journal.pone.0014734>
- Brito, J. C., Tarroso, P., Vale, C. G., Martínez-Freiría, F., Boratyński, Z., Campos, J., ... Carvalho, S. B. (2016). Conservation Biogeography of the Sahara-Sahel: Additional protected areas are needed to secure unique biodiversity. *Diversity and Distributions*, 22, 371–384. <https://doi.org/10.1111/ddi.12416>
- Buckley, R. (2009). Evaluating the net effects of ecotourism on the environment : A framework, first assessment and future research. *Journal of Sustainable Tourism*, 17(6), 643–672. <https://doi.org/10.1080/09669580902999188>
- Campos, J. C., Martínez-Freiría, F., Sousa, F. V., Santarém, F., & Brito, J. C. (2016). Update of distribution , habitats , population size , and threat factors for the West African crocodile in Mauritania. *Amphibia-Reptilia*, 37(3), 325–330. <https://doi.org/10.1163/15685381-00003059>
- Campos, J. C., Sillero, N., Brito, J. C. (2011). Normalized difference water indexes have dissimilar performances in detecting seasonal and permanent water in the Sahara-Sahel transition zone. *Journal of Hydrology*, 464-465, 438-446.
- Castro, E. V. De, Souza, T. B., & Thapa, B. (2015). Determinants of Tourism Attractiveness in the National Parks of Brazil. *Parks*, 21(2), 51–62.
- Chan, K. M. A., Shaw, M. R., Cameron, D. R., Underwood, E. C., & Daily, G. C. (2006). Conservation planning for ecosystem services. *PLoS Biology*, 4(11), 2138–2152. <https://doi.org/10.1371/journal.pbio.0040379>
- Chhetri, P., & Arrowsmith, C. (2008). GIS-based Modelling of Recreational Potential of Nature-Based Tourist Destinations. *Tourism Geographies*, 10(2), 233–257. <https://doi.org/10.1080/14616680802000089>
- Cooper, A., Shine, T., McCann, T., & Tidane, D. A. (2006). An ecological basis for sustainable land use of Eastern Mauritanian wetlands. *Journal of Arid Environments*, 67, 116–141. <https://doi.org/10.1016/j.jaridenv.2006.02.003>
- Dhami, I., Deng, J., Burns, R. C., & Pierskalla, C. (2014). Identifying and mapping forest-based ecotourism areas in West Virginia - Incorporating visitors' preferences. *Tourism Management*, 42, 165–176. <https://doi.org/10.1016/j.tourman.2013.11.007>
- Dhami, I., Deng, J., Strager, M., & Conley, J. (2017). Suitability-sensitivity analysis of nature-based tourism using geographic information systems and analytic hierarchy process. *Journal of Ecotourism*, 16(1), 41–68. <https://doi.org/10.1080/14724049.2016.1193186>
- Diamantis, D. (1999). The Concept of Ecotourism : Evolution and Trends. *Current Issues in Tourism*, 2(2–3), 93–122. <https://doi.org/10.1080/13683509908667847>
- Donohoe, H. M., & Needham, R. D. (2006). Ecotourism: The Evolving Contemporary Definition. *Journal of Ecotourism*, 5(3), 192–210. <https://doi.org/10.2167/joe152.0>
- Durant, S. M., Pettorelli, N., Bashir, S., Woodroffe, R., Wachter, T., Ornellas, P. de, ... Baillie, J. (2012). Forgotten Biodiversity in Desert Ecosystems. *Science*, 336(6087), 1379–1380. <https://doi.org/10.1126/science.336.6087.1379>
- Environmental Systems Research Institute (ESRI). (2012). ArcGIS Release 10.1. Redlands, CAFAO. (2013). Low-Income Food-Deficit Countries (LIFDC) — List for 2013. Retrieved February 23, 2017, from [http://www.fao.org/countryprofiles/lifdc/en/FAO 2011](http://www.fao.org/countryprofiles/lifdc/en/FAO%2011)
- Fennell, D. A. (2001). A Content Analysis of Ecotourism Definitions. *Current Issues in*

- Tourism*, 4(5), 403–421. <https://doi.org/10.1080/13683500108667896>
- Fennell, D. A. (2015). *Ecotourism* (4th ed.). Oxon and New York: Routledge.
- Fennell, D., & Weaver, D. (2005). The Ecotourism Concept and Tourism-Conservation Symbiosis. *Journal of Sustainable Tourism*, 13(4), 373–390. <https://doi.org/10.1080/09669580508668563>
- Fraley, C., & Raftery, A. (2002). Model-based clustering, discriminant analysis, and density estimation. *Journal of the American Statistical Association*, 97, 611–631.
- Fraley, C., Raftery, A., Murphy, T. B., & Scrucca, L. (2012). mclust Version 4 for R: Normal Mixture Modeling for Model-Based Clustering, Classification, and Density Estimation.
- Fung, T., & Wong, F. K. K. (2007). Ecotourism planning using multiple criteria evaluation with GIS. *Geocarto International*, 22(2), 87–105. <https://doi.org/10.1080/10106040701207332>
- Honey, M. (2008). *Ecotourism and sustainable development: Who owns paradise?* (2nd Ed.). Washington DC: Island Press.
- Hosni, E. (2000). Strategy for sustainable tourism development in the Sahara.
- Hotelling, H. (1933). Analysis of a complex of statistical variables into principal components. *Journal of Educational Psychology*, 24(6), 417–441. <https://doi.org/10.1037/h0071325>
- Kienast, F., Degenhardt, B., Weilenmann, B., Wäger, Y., & Buchecker, M. (2012). GIS-assisted mapping of landscape suitability for nearby recreation. *Landscape and Urban Planning*, 105(4), 385–399. <https://doi.org/10.1016/j.landurbplan.2012.01.015>
- Kirkby, C. A., Giudice-Granados, R., Day, B., Turner, K., Velarde-Andrade, L. M., Dueñas-Dueñas, A., ... Yu, D. W. (2010). The market triumph of ecotourism: An economic investigation of the private and social benefits of competing land uses in the Peruvian Amazon. *PLoS ONE*, 5(9), 22–27. <https://doi.org/10.1371/journal.pone.0013015>
- Kirkby, C. A., Giudice, R., Day, B., Turner, K., Soares-Filho, B. S., Oliveira-Rodrigues, H., & Yu, D. W. (2011). Closing the ecotourism-conservation loop in the Peruvian Amazon. *Environmental Conservation*, 38(1), 6–17. <https://doi.org/10.1017/S0376892911000099>
- Kliskey, A. D. (2000). Recreation terrain suitability mapping: A spatially explicit methodology for determining recreation potential for resource use assessment. *Landscape and Urban Planning*, 52(1), 33–43. [https://doi.org/10.1016/S0169-2046\(00\)00111-0](https://doi.org/10.1016/S0169-2046(00)00111-0)
- Lindsey, P. A., Alexander, R. R., du Toit, J. T., & Mills, M. G. L. (2005). The potential contribution of ecotourism to African wild dog *Lycaon pictus* conservation in South Africa. *Biological Conservation*, 123(3), 339–348. <https://doi.org/10.1016/j.biocon.2004.12.002>
- Milcu, A. I., Hanspach, J., Abson, D., & Fischer, J. (2013). Cultural ecosystem services: A literature review and prospects for future research. *Ecology & Society*, 18(3), 44–88. <https://doi.org/10.5751/ES-05790-180344>
- Mossaz, A. C., Buckley, R., & Castley, J. G. (2015). Ecotourism Contributions to Conservation of African Big Cats. *Journal for Nature Conservation*, 28, 112–118. <https://doi.org/10.1016/j.jnc.2015.09.009>
- Nahuelhual, L., Carmona, A., Lozada, P., Jaramillo, A., & Aguayo, M. (2013). Mapping recreation and ecotourism as a cultural ecosystem service: An application at the local level in Southern Chile. *Applied Geography*, 40, 71–82. <https://doi.org/10.1016/j.apgeog.2012.12.004>
- Paracchini, M. L., Zulian, G., Kopperoinen, L., Maes, J., Schägner, J. P., Termansen, M., ... Bidoglio, G. (2014). Mapping cultural ecosystem services: A framework to assess the potential for outdoor recreation across the EU. *Ecological Indicators*, 45, 371–385. <https://doi.org/10.1016/j.ecolind.2014.04.018>
- Pavoine, S., Dufour, A. B., & Chessel, D. (2004). From dissimilarities among species to dissimilarities among communities: A double principal coordinate analysis. *Journal of Theoretical Biology*, 228(4), 523–537. <https://doi.org/10.1016/j.jtbi.2004.02.014>
- Peña, L., Casado-Arzuaga, I., & Onaindia, M. (2015). Mapping recreation supply and demand using an ecological and a social evaluation approach. *Ecosystem Services*, 13, 108–118. <https://doi.org/10.1016/j.ecoser.2014.12.008>
- Penteriani, V., López-Bao, J. V., Bettega, C., Dalerum, F., Delgado, M. del M., Jerina, K., ... Ordiz, A. (2017). Consequences of brown bear viewing tourism: A review. *Biological*

- Conservation*, 206, 169–180. <https://doi.org/10.1016/j.biocon.2016.12.035>
- Pina, I. P. A., & Delfa, M. T. D. (2005). Rural tourism demand by type of accommodation. *Tourism Management*, 26(6), 951–959. <https://doi.org/10.1016/j.tourman.2004.06.013>
- R Core Team. (2016). R: A Language and Environment for Statistical Computing. Retrieved from <https://www.r-project.org/>
- Reimer, J. K., & Walter, P. (2013). How do you know it when you see it? Community-based ecotourism in the Cardamom Mountains of southwestern Cambodia. *Tourism Management*, 34, 122–132. <https://doi.org/10.1016/j.tourman.2012.04.002>
- Saarinen, J. (2006). Traditions of Sustainability in Tourism Studies. *Annals of Tourism Research*, 33(4), 1121–1140. <https://doi.org/10.1016/j.annals.2006.06.007>
- Saarinen, J., & Rogerson, C. M. (2013). Tourism and the Millennium Development Goals: perspectives beyond 2015. *Tourism Geographies*, 16(1), 23–30. <https://doi.org/10.1080/14616688.2013.851269>
- Sanderson, E. W., Jaiteh, M., Levy, M. A., Redford, K. H., Wannebo, A. V., & Woolmer, G. (2002). The Human Footprint and the Last of the Wild. *BioScience*, 52(10), 891–904. [https://doi.org/https://doi.org/10.1641/0006-3568\(2002\)052\[0891:THFATL\]2.0.CO;2](https://doi.org/https://doi.org/10.1641/0006-3568(2002)052[0891:THFATL]2.0.CO;2)
- Santarém, F., & Paiva, F. (2015). Conserving desert biodiversity through ecotourism. *Tourism Management Perspectives*, 16, 176–178. <https://doi.org/10.1016/j.tmp.2015.07.016>
- Santarém, F., Silva, R., & Santos, P. (2015). Assessing ecotourism potential of hiking trails: A framework to incorporate ecological and cultural features and seasonality. *Tourism Management Perspectives*, 16, 190–206. <https://doi.org/10.1016/j.tmp.2015.07.019>
- Scheyvens, R. (1999). Ecotourism and the empowerment of local communities. *Tourism Management*, 20(2), 245–249. [https://doi.org/10.1016/S0261-5177\(98\)00069-7](https://doi.org/10.1016/S0261-5177(98)00069-7)
- Steven, R., Castley, J. G., & Buckley, R. (2013). Tourism Revenue as a Conservation Tool for Threatened Birds in Protected Areas. *PLoS ONE*, 8(5), 1–8. <https://doi.org/10.1371/journal.pone.0062598>
- Stronza, A. (2007). The Economic Promise of Ecotourism for Conservation. *Journal of Ecotourism*, 6(3), 210–230. <https://doi.org/10.2167/joe177.0>
- Sung, H. H. (2004). Classification of Adventure Travelers: Behavior, Decision Making, and Target Markets. *Journal of Travel Research*, 42(4), 343–356. <https://doi.org/10.1177/0047287504263028>
- Telleria, J. L., Ghaillani, H. E. M., Fernandez-Palacios, J. M., Bartolome, J., & Montiano, E. (2008). Crocodiles *Crocodylus niloticus* as a focal species for conserving water resources in Mauritanian Sahara. *Oryx*, 42(2), 292–295. <https://doi.org/10.1017/s0030605308007850>
- Tryon, R. C. (1939). *Cluster analysis: Correlation profile and orthometric (factor) analysis for the isolation of unities in mind and personality*. Edwards brothers.
- UNDP. (2016). *Human Development Report 2016. Human Development for Everyone*. New York, USA.
- UNESCO. (2003). *Towards a strategy for the sustainable development of tourism in the Sahara, in the context of combating poverty. The Sahara of Cultures and People*. Paris, France.
- Vale, C. G., & Brito, J. C. (2015). Desert-adapted species are vulnerable to climate change: Insights from the warmest region on Earth. *Global Ecology and Conservation*, 4, 369–379. <https://doi.org/10.1016/j.gecco.2015.07.012>
- Vale, C. G., Pimm, S. L., & Brito, J. C. (2015). Overlooked mountain rock pools in deserts are critical local hotspots of biodiversity. *PLoS ONE*, 10(2), e0118367. <https://doi.org/10.1371/journal.pone.0118367>
- Veríssimo, D., Fraser, I., Gir, W., Campos, A. A., Smith, R. J., & Macmillan, D. C. (2014). Evaluating Conservation Flagships and Flagship Fleets. *Conservation Letters*, 7(3), 263–270. <https://doi.org/10.1111/conl.12070>
- Veríssimo, D., Fraser, I., Groombridge, J., Bristol, R., & Macmillan, D. C. (2009). Birds as tourism flagship species: a case study of tropical islands Research methods. *Animal Conservation*, 12, 549–558. <https://doi.org/10.1111/j.1469-1795.2009.00282.x>
- Veríssimo, D., MacMillan, D. C., & Smith, R. J. (2011). Toward a systematic approach for

- identifying conservation flagships. *Conservation Letters*, 4(1), 1–8.
<https://doi.org/10.1111/j.1755-263X.2010.00151.x>
- Veríssimo, D., Pongiluppi, T., Santos, M. C. M., Develey, P. F., Fraser, I., Smith, R. J., & Macmillan, D. C. (2013). Using a Systematic Approach to Select Flagship Species for Bird Conservation. *Conservation Biology*, 28(1), 269–277. <https://doi.org/10.1111/cobi.12142>
- Waldron, A., Mooers, A. O., Miller, D. C., Nibbelink, N., Redding, D., & Kuhn, T. S. (2013). Targeting global conservation funding to limit immediate biodiversity declines. *Proceedings of the National Academy of Sciences*, 110(29), 1–5.
<https://doi.org/10.5061/dryad.p69t1>
- Walpole, M. J., & Leader-Williams, N. (2002). Tourism and flagship species in conservation. *Biodiversity and Conservation*, 11, 543–547. <https://doi.org/10.1023/A:1014864708777>
- Weaver, D. B. (2001). *The encyclopedia of ecotourism*. Wallingford: CABI.
- Weaver, D. B. (2002). The evolving concept of ecotourism and its potential impacts. *International Journal of Sustainable Development*, 5(3), 251–264.
<https://doi.org/10.1504/IJSD.2002.003753>
- Weaver, D. B. (2005). Comprehensive and minimalist dimensions of ecotourism. *Annals of Tourism Research*, 32(2), 439–455. <https://doi.org/10.1016/j.annals.2004.08.003>
- WEF. (2017). *The Travel & Tourism Competitiveness Report 2017*. Geneva, Switzerland.
- Wong, F. K. K., & Fung, T. (2015). Ecotourism planning in Lantau Island using multiple criteria decision analysis with geographic information system. *Environment and Planning B: Planning and Design*, 43(4), 640–662. <https://doi.org/10.1177/0265813515618583>