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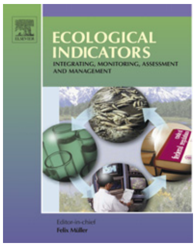

Demonstration of a satellite-based index to monitor habitat at continental-scales

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ABSTRACT

An important initial step in the conservation and sustainable management of the Earth's biodiversity is to implement systems to both identify and subsequently monitor components of biological diversity, along with developing a better understanding of the processes that significantly threaten their conservation or sustainable use. Key factors in both species diversity and richness are related to environmental heterogeneity which is driven by temporal and spatial variation in the biological, physical, and chemical features of the environment. These environmental characteristics are manifest through the condition and change in vegetation productivity (considered as an integrated response of vegetation to climate and soil conditions). Earth observation is uniquely capable of synoptically covering large areas of the planet in a repeatable, and cost effective manner, and is a well-established technology for detecting terrestrial vegetation productivity. A recently developed dynamic habitat index (DHI), based on satellite observations of the fraction of radiation absorbed by the canopy (fPAR), has been shown to effectively cluster remotely sensed observations into a range of habitat regimes which in turn have been related to breeding bird surveys in the Canadian Province of Ontario and across the conterminous United States. With evidence that the index is well correlated with species diversity, we consider, in this subsequent paper, whether such an index is a suitable candidate as a continental index to characterize and subsequently monitor habitat conditions. To do so, we first utilise available fPAR data available from 2000 to 2005 over North America, and apply the index. Using information on continental terrestrial ecozones and their ecological distinctiveness, we then compare and contrast the index and utilize trajectory analysis to assess what changes have occurred in the index over the 6-year time period and possible implications for continental biodiversity. The potential application of the index is the discussed.

1. Introduction

There is global consensus that the present loss of biodiversity is inextricably linked with human development, and that the conservation and sustainable use of our remaining biological diversity is critical for both current and future generations of life on Earth (UNEP, 2002). An important initial step in understanding what terrestrial biological diversity exists is for resource agencies to implement systems which can identify and monitor components of biological diversity, along with the processes that significantly threaten their conservation (CBD, 1992). This challenge has led to an increased

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awareness of the need for relevant biological indicators from which biodiversity can be measured (Leyequien et al., 2007) with indicators such as species, habitats, and eco-regional characteristics, which can be sampled in the field, categorized, and subsequently interpreted, often promoted as critical information layers in ongoing decision making.

Spatial, environmental, heterogeneity is one of the driving factors explaining species richness (Stoms and Estes, 1993) with increases in heterogeneity associated with richer species assemblages when compared to simple ecosystems (Simpson, 1949; Huston, 1994). This has principally been attributed to the creation of niche differentiation between species with the variation in resources allowing competing species to partition more effectively (Leyequien et al., 2007; Loreau, 1998). Factors contributing to environmental heterogeneity include the temporal and spatial variation in the biological, physical, and chemical components of the environment (Leyequien et al., 2007) which in turn manifests itself through changes in vegetation productivity and biomass due the integrated response of vegetation to climate and soil conditions. A direct link between productivity and species richness, distribution and abundance of individuals is therefore expected, and has been demonstrated (Currie, 1991; Gaston and Blackburn, 2000; Oindo and Skidmore, 2002; Walker et al., 1992; Nightingale et al., 2008).

The link between landscape productivity and fauna species richness is essentially an ecological one, based principally on food to meet metabolic requirements and habitat for shelter and nesting (Berry et al., 2007). The movement and migration of fauna in particular is governed by the provision of food and habitat with the shape and size of individuals home ranges a fundamental ecological parameter for modeling of species (Herfindal et al., 2005). Understanding species spatial distributions is therefore important for management and conservation to ensure there is a correspondence, for example between size of management unit and the home range of the species they are designed to conserve (Herfindal et al., 2005). In addition, information on the spatial scale at which management decisions are made is also critical for deriving population estimates using either formal population viability approaches or when simply extrapolating from surveys of species distributions (Nilsen et al., 2005). Unlike plant species distributions however, faunal home ranges vary by orders of magnitude for different species groups due to differences in body size, feeding behaviour, and habitat. Furthermore, substantial variation can exist within a single species, with home ranges and populations varying by factors of 10–1000 (Gompper and Gittleman, 1991) depended on the productivity of the area. The temporal as well as the spatial variations in the distribution and productivity of vegetation is therefore directly lined to both the persistence and existence of fauna.

The task of identifying and monitoring biodiversity at large, regional or national scales, using traditional surveying techniques such as ground or aerial overview surveying, remains logistically difficult and financially prohibitive and as a result there remains a paucity of data on continental and global patterns of species distributions (Brooks et al., 2002). Earth observation data is uniquely capable of synoptically covering large areas of the planet in a repeatable and cost effective manner. Data from these satellite sensors has already provided significant insights into biological diversity and the underlying ecological processes (Berry and Roderick, 2002; Running et al., 2004; Turner et al., 2003). Satellite remote sensing has been shown to be effective at the broad scale detection and delineation of anthropogenic and natural disturbances driving the loss of global biological diversity (Achard et al., 2002; Potter et al., 2003). In particular, remote sensing offers the capacity to monitor vegetation productivity at a number of temporal and spatial scales (Potter et al., 2003; Running et al., 2004; Fraser and Latifovic, 2005; Coops et al., 2006). In addition, vegetation readily reflects disturbance events such as fire, blow down, harvested, or consumed by herbivores making it an ideal indicator of landscape condition and as such provides an important way to evaluate the current landscape production as well as provide a mechanism to detect changes in habitat due to disturbance.

One key approach to monitor the terrestrial environment is to compute and monitor the normalized difference vegetation index (NDVI), a normalized ratio of the red and infrared reflectance channels, as it provides an indication of photosynthetic activity of chlorophyll based vegetation (Tucker, 1979) has been used extensively to predict biophysical parameters of forests (Wulder, 1998), and as a means of examining how environmental changes affect the distribution of both plants and animals (Pettorelli et al., 2005). For example a long-term archive of NDVI data derived from the advanced very high resolution radiometer (AVHRR) onboard the NOAA satellites, has been successfully used to provide estimates of the inter-annual variability of global vegetation activity and to link broad scale changes in NDVI to climate drivers (Myneni et al., 1998). More recently, the enhanced vegetation index (EVI), a similar index, but one less affected by the atmosphere or soil effects, has also been related to production, both regionally and globally (Huete et al., 2002). For mammals increased levels of vegetation production as predicted from NDVI have been linked with increases in mammal abundance including ostrich and wildebeest (Verlinden and Masogo, 1997) and higher NDVI values have also been associated with seasonal migration of herds of wildebeest in the Serengeti-Mara (Musiega and Kazadi, 2004). Skidmore et al. (2003) compared both avian and mammalian species richness with the NDVI however found that in general climatic parameters were in a general a better predictor of species richness than satellite derived NDVI. The relationship between annual vegetative biomass (derived from NDVI) and avian species diversity was assessed in Senegal (Jorgensen and Nohr, 1996) with some success with strong relationships between satellite greenness and bird species richness. Similarly Hurbert and Haskell (2003) found, at fine spatial scales, NDVI to be a good predictor of species richness and habitat heterogeneity a better predicted of species richness at more coarse spatial resolutions. Similarly Hawkins et al. (2003) found that both satellite derived and climatic productivity indicators (NDVI and actual evapo-transpiration) correlated well with bird diversity data in North America.

Another key metric of vegetation production in addition to the NDVI, is the fraction of photosynthetically active radiation