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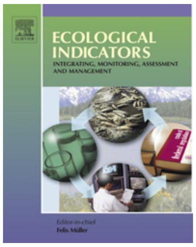

The development of a Canadian dynamic habitat index using multi-temporal satellite estimates of canopy light absorbance

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ABSTRACT

Monitoring patterns of fauna diversity across the landscape, both spatially and temporally, presents special challenges due to the dynamic nature of populations and complex interactions with the local and regional environment. One area where progress is being made is the development of relationships between regional biodiversity with indirect indicators or surrogates, such as vegetative production. In this paper we discuss implementation of a dynamic habitat index, originally developed in Australia, to Canadian conditions. The index, based on the fraction of photosynthetically active radiation (fPAR) absorbed by vegetation, a variable which is analogous to green vegetation cover, is derived solely from satellite data. The index utilizes time series of satellite observations of greenness to derive three indicators of the underlying vegetation dynamics; the cumulative annual greenness, the minimum level of perennial cover, and the degree of vegetation seasonality. We apply the index across Canada and compare the three components by ecozones, demonstrating that Canada's terrestrial environment can effectively be clustered into five major dynamic habitat regimes. These range from those with low cumulative greenness and highly seasonal variation in cover, to regimes which have high canopy light absorbance with limited seasonality and continuous annual green cover. By comparing data from multiple years, our analysis indicates that a number of these ecozones have experienced changes in their composition over the past 6 years. We believe this methodology can provide an initial stratification of large areas for biodiversity monitoring and can be used to focus finer scale approaches to specific regions of interest or monitor regions too remote for comprehensive field surveys.

1. Introduction

Movement of fauna presents special challenges for the conservation of biodiversity as species are often dependent on a range of landscape ecosystems to provide food and habitat for their survival. Home range size and shape are among the most fundamental ecological parameters for species modeling and the analysis of factors influencing home range size has received constant research and management attention for the past quarter century. Understanding

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species use of space is vital for management and conservation to, for example, designate the size of management units to suit the species they are designed to protect (Herfindal et al., 2005).

The past two decades have seen the development of relationships between herbivore biomass and patterns of productivity based on the simple premise that the key requirements for existence of an organism are a supply of food to meet its metabolic needs and habitat for shelter and nesting (Olff et al., 2002; Berry et al., 2007). As survival and reproduction are often food limited, the availability of food in time and space is an important factor influencing the spatial organization of species (McLoughlin and Ferguson, 2000a). In addition, vegetation components also provide shelter and nesting resources for many animals (Cork and Catling, 1996; Berry et al., 2007). As a result, temporal changes in the distribution and growth of vegetation is of major importance to the existence and persistence of fauna.

In areas were food is abundant and predictable in time (e.g., seasonality) and space (e.g., patchiness) small home ranges may be more likely to occur as animals are able to maximize energy intake over less area with or without territorial defense (McLoughlin et al., 2000b) and may be expected to have non-migratory movement patterns. In contrast, in areas with less food availability, more patchy distribution of vegetation or with seasonal depletion, species may have larger home ranges. These species may also, in some circumstances, face increases in competitor density and intruder pressure thus exhibiting dispersive behavior, surviving by relocating annually based on available food and habitat requirements (Berry et al., 2007; Woinarski, 1992). These types of relationships between home range, abundance and primary productivity/food availability have been developed for a range of species including Eurasian lynx where it was found that home range was inversely proportional to environmental productivity and seasonality (Herfindal et al., 2005). Similarly, Nilsen et al. (2005) found that leopard, wolf, and fisher home range sizes are all associated with measures of vegetation productivity including rainfall, soil nutrient status, and water availability. For African herbivores, East (1984) found measures of productivity could be associated with patterns of overall biodiversity distribution.

Land use change, disturbances such as harvesting, fire, and insect infestations and potential increases in climate variability further complicate the management of individual species. For example, a mountain pine beetle epidemic in Western Canada has affected an estimated 9.2 million ha in 2006, compared with 164,000 ha in 1999 (Westfall, 2007). Similarly, overgrazing by animals, such as Caribou on lichen (Theaun et al., 2005), can result in landscape degradation persisting for as long as 50 years (Moser et al., 1979) due to the slow growth and ecological sensitivity of northern environments.

These factors place increasing demands on land managers who seek to ensure species protection whilst experiencing a general reduction in funds for assessing patterns of species diversity (Bailey et al., 2004). As a result, cost effective methods are desperately needed to explain, predict, and map patterns of species abundance and movement in space/time and to better understand how particular ecological groups of species respond to complex landscape disturbance and change.

One way of endeavoring to track resource availability through space and time is by utilizing readily available information on vegetation and land use acquired by Earth observing satellites. Remote sensing offers an ideal technology to monitor and assess changes in vegetation cover and condition at a variety of spatial and temporal scales (e.g., Running et al., 2004). Leafy vegetation cover is the most fragile and therefore perhaps the single most vulnerable biotic component of terrestrial ecosystems with major disturbance events clearly discernable from remote observations (Potter et al., 2003; Fraser et al., 2005; Fraser and Latifovic, 2005; Coops et al., 2006). Foliage burns relatively easily, can be readily blown down, cut to the ground, or consumed by herbivores. Shed leaves rapidly decompose to blend in with background soil attributes. As a result, remote sensing of green vegetation cover provides a useful means to assess both current vegetative production as well as the detection of changes in production due to disturbance.

Since the launch of the first remote sensing satellites in the late 1970s green vegetation cover has been monitored daily (Myneni et al., 1998) across the globe, making available a time series of measurements that facilitate spatial–temporal analysis of vegetation production. A key metric of vegetation production from satellite imagery is the prediction of the fraction of photosynthetically active radiation (or fPAR) intercepted by vegetation, which is analogous to greenness cover (Knyazikhin et al., 1998) and ranging from zero (on barren land) to one (for dense cover). In theory, the higher the average fPAR level observed over the course of a seasonal plant growing cycle, the more dense the green leaf cover, and the less disturbed the vegetation cover. Conversely, the lower the average fPAR, the landscape is inferred to be less productive and subject to disturbance. fPAR is linearly related to the positive end of the more commonly used normalized difference vegetation index (NDVI), a measure of reflected radiation. Despite fPAR being less commonly applied, it is fPAR, not NDVI, that is required to calculate the rate at which carbon dioxide and energy from sunlight are assimilated into carbohydrates during photosynthesis of plant tissues, with summation of carbon assimilated by the vegetation canopy over time yielding the landscape gross primary productivity (Monteith, 1972). Potter et al. (2003) demonstrated that fPAR observed by daily satellite observations could successfully be used to monitor large-area ecosystem behavior. Over the entire globe, 10 years of greenness observations were analyzed to assess changes in the vegetation pattern due to a range of major ecosystem disturbances such as fire and insects. Nilsen et al. (2005) was among the first to link satellite measured greenness with measures of fauna diversity. They compared variations in the mean and seasonal greenness over a 2-year period with the home ranges of 12 carnivore species in the northern hemisphere to test the hypothesis of Harestad and Bunnell (1979) that species home ranges should decrease as a function of increasing productivity. Results indicated that the accuracy of prediction of 8 of the 12 species home range sizes was improved using the greenness observations.