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Evaluating MODIS data for mapping wildlife habitat distribution

Andrés Viña [a,*], Scott Bearer [a,1], Hemin Zhang [b], Zhiyun Ouyang [c], Jianguo Liu [a]

[a] Center for Systems Integration and Sustainability, Department of Fisheries and Wildlife, Michigan State University, East Lansing, MI, USA
[b] China's Center for Giant Panda Research and Conservation, Wolong Nature Reserve, Sichuan, China
[c] State Key Lab of Urban and Regional Ecology, Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing, China

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Abstract

Habitat distribution models have a long history in ecological research. With the development of geospatial information technology, including remote sensing, these models are now applied to an ever-increasing number of species, particularly those located in areas in which it is logistically difficult to collect habitat data in the field. Many habitat studies have used data acquired by multi-spectral sensor systems such as the Landsat Thematic Mapper (TM), due mostly to their availability and relatively high spatial resolution (30 m/pixel). The use of data collected by other sensor systems with lower spatial resolutions but high frequency of acquisitions has largely been neglected, due to the perception that such low spatial resolution data are too coarse for habitat mapping. In this study we compare two models using data from different satellite sensor systems for mapping the spatial distribution of giant panda habitat in Wolong Nature Reserve, China. The first one is a four-category scheme model based on combining forest cover (derived from a digital land cover classification of Landsat TM imagery acquired in June, 2001) with information on elevation and slope (derived from a digital elevation model obtained from topographic maps of the study area). The second model is based on the Ecological Niche Factor Analysis (ENFA) of a time series of weekly composites of WDRVI (Wide Dynamic Range Vegetation Index) images derived from MODIS (Moderate Resolution Imaging Spectroradiometer – 250 m/pixel) for 2001. A series of field plots was established in the reserve during the summer–autumn months of 2001–2003. The locations of the plots with panda feces were used to calibrate the ENFA model and to validate the results of both models. Results showed that the model using the seasonal variability of MODIS-WDRVI had a similar prediction success to that using Landsat TM and digital elevation model data, albeit having a coarser spatial resolution. This suggests that the phenological characterization of the land surface provides an appropriate environmental predictor for giant panda habitat mapping. Therefore, the information contained in remotely sensed data acquired with low spatial resolution but high frequency of acquisitions has considerable potential for mapping the habitat distribution of wildlife species.

Keywords: Giant panda; Habitat distribution models; Landsat Thematic Mapper (TM); Moderate Resolution Imaging Spectroradiometer (MODIS); Wide Dynamic Range Vegetation Index (WDRVI); Wolong Nature Reserve (China)

1. Introduction

Deciding which areas are the most important for conservation and management requires a precise knowledge of the locations and spatial distribution of target species habitats (Rushton et al., 2004). This is particularly important for both invasive (Peterson, 2005; Morisette et al., 2006) and endangered (Engler et al., 2004; Xu et al., 2006) species for which such knowledge can be used to establish strategies for managing their population dynamics (Rushton et al., 2004). It is also important when the habitat of the target species for conservation encompasses the habitat of numerous other plant and animal species (e.g., flagship species), therefore establishing management efforts that embrace entire ecosystems. Such is the case of the endangered giant panda (*Ailuropoda melanoleuca*), which not only is a global icon for biodiversity conservation, but its habitat comprises several types of sub-alpine forest ecosystems (Reid & Hu, 1991; Taylor & Qin, 1993). Therefore, efforts to mitigate the habitat reduction of this conservation icon can also promote the conservation of entire forest ecosystems.

* Corresponding author. Center for Systems Integration and Sustainability, 1405 S. Harrison Road, Suite 115 Mainly Miles Bldg., Michigan State University, East Lansing, MI 48823-5243, USA. Tel.: +1 517 432 5078.
E-mail address: vina@msu.edu (A. Viña).
[1] Current address: The Nature Conservancy, Williamsport, PA, USA.

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The giant panda once ranged throughout most of eastern and southern China, northern Vietnam, and northern Myanmar (Pan et al., 2001), but it has been restricted in recent decades to six major mountainous areas in China (Reid & Gong, 1999; Loucks et al., 2001). The main reasons for the reduction in its geographic range are the human-induced loss and fragmentation of broadleaf deciduous and coniferous montane forests, as the pandas rely on forest overstory as shelter and understory bamboo as staple food (Schaller et al., 1985; Taylor & Qin, 1987, 1993; Reid & Hu, 1991; Reid et al., 1991; Liu et al., 1999). Conservation of this species constitutes an enormous challenge and a national priority for China, since there are only about 1600 individuals in the wild (Wei et al., 2006), distributed in approximately 24 isolated populations across its current estimated geographic range (Reid & Gong, 1999; Loucks et al., 2001; Yan, 2005).

The increasing availability of remotely sensed data acquired by operational satellites, coupled with the development of geographic information systems (GIS) capable of storing and analyzing the enormous amounts of spatial data generated by remote sensing techniques, has led to their widespread use in habitat mapping (Rushton et al., 2004). The common approach employed for habitat mapping using remotely sensed data has been the generation of non-hierarchical land cover classifications, combined with ancillary information such as digital elevation models (DEM) derived from topographic maps (e.g., Luoto et al., 2002a,b). Most of these exercises have favored remotely sensed data acquired at spatial resolutions similar to field observations (e.g., 30×30 m field plots; Seto et al., 2004), with Landsat Thematic Mapper (TM) data being the most highly used, primarily due to their availability. Giant panda habitat mapping has not escaped this trend since it has primarily relied on land cover classifications of Landsat imagery using visual interpretations (MacKinnon & De Wulf, 1994; Liu et al., 2001), as well as digital image processing techniques such as unsupervised (Loucks et al., 2003; Viña et al., 2007) and supervised (Xu et al., 2006) procedures. However, these techniques have not been able to detect the spectral signature of understory bamboo cover. That is important for characterizing the panda habitat (Linderman et al., 2004), since the optical response of the vegetation captured by the satellite sensor is a complex non-linear combination of overstory and understory canopy components (Borel & Gerstl, 1994). Therefore, other digital processing techniques based on neural networks have been proposed in order to detect the presence of understory bamboo in Landsat imagery (Linderman et al., 2004; Liu et al., 2004), and have been shown to modify the areal estimates of panda habitat (Linderman et al., 2005).

Furthermore, due to the low temporal resolution of Landsat imagery, the data used in habitat analyses usually correspond to snapshots at particular dates and seasons that fail to recognize the seasonal nature of habitats (Nielsen et al., 2003). Although some studies have acknowledged that multi-temporal data enable the classification of seasonally changing habitats, and have used two or more Landsat scenes acquired during different seasons (e.g., Luoto et al., 2002a,b), the phenological progression of the vegetation has not been fully evaluated for habitat characterization and mapping.

High temporal resolution data, such as the widely available global datasets derived from the Advanced Very High Resolution Radiometer (AVHRR) or the Moderate Resolution Imaging Spectroradiometer (MODIS), can be used to evaluate the phenological progression of the vegetation, and potentially constitute suitable environmental predictors for habitat mapping (Morisette et al., 2006). Nevertheless, the use of these data for habitat mapping has been largely neglected due mostly to their coarse spatial resolutions (250 m–1 km/pixel).

The main goal of this study is to evaluate the usefulness of MODIS time series imagery, as compared to the traditional classification of single-date Landsat TM imagery, for mapping the habitat for the endangered giant pandas. The rationale for this comparison is to examine whether data acquired with a high temporal resolution (as that of MODIS), although acquired with coarser spatial resolutions, can also be successfully used for mapping wildlife habitat. In addition, in order to implement comprehensive sustainable management practices for the conservation of the species such as establishment of nature reserves, buffer areas, corridors and re-introduction sites, it is important to analyze the distribution of existing panda habitat in its entire geographic range. Therefore, an important consideration for the usefulness of MODIS, as opposed to Landsat data, is their coverage of vast areas (regional to global extents), suitable for analyzing the habitat distribution of the entire geographic range of the species.

2. Methods

2.1. Study area

Wolong Nature Reserve is located in Sichuan Province, southwest China (Fig. 1). It was initially established in 1963 with an area of about 200 km^2 and then expanded to its current size of ca. 2000 km^2 in 1975 (Li et al., 2003). It is one of the largest nature reserves in China designed to protect the endangered giant pandas. Wolong Nature Reserve is part of the international Man and the Biosphere Reserve Network (He et al., 1996), protects approximately 10% of the entire wild panda population (Zhang et al., 1997), and has drawn unmatched domestic and international attention (Liu et al., 1999).

Situated the transition between the Sichuan Basin and the Qinghai-Tibet Plateau, it is characterized by high mountains and deep valleys, with elevations between 1200 m and 6250 m (Fig. 1). Together with this strong altitudinal gradient there is a high variation in topography, soils and climate that leads to a diverse flora and fauna. Vegetation in the reserve is dominated by evergreen and deciduous broadleaf forests at lower elevations (around 1500 m) and sub-alpine coniferous forests at higher elevations (around 2700 m; Schaller et al., 1985), with a dense understory dominated by bamboo species such as *Bashania fabri* and *Fargesia robusta* that are the staple food of the giant pandas in the reserve (Schaller et al., 1985; Taylor & Qin, 1987, 1993; Reid & Hu, 1991; Reid et al., 1991).

2.2. Giant panda occurrence

Being a bashful species, with only around 1600 individuals left in the wild (Wei et al., 2006) and a large distribution range, the endangered giant pandas are extremely difficult to encounter