Technology Innovation

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Linking wildlife populations with ecosystem change:

State-of-the-art satellite ecology for national park science

By Mark Hebblewhite

AS HUMAN IMPACTS INCREASE IN NATIONAL PARKS and the greater ecosystems surrounding them, the National Park Service faces the difficulty of monitoring ecosystem changes and responses of key wildlife indicator species within parks. Responses of bison to trail grooming in Yellowstone National Park (Wyoming, Montana , and Idaho) and control of the animals once they leave the park (Bruggeman et al. 2007), migration of wildlife across park boundaries (Griffith et al. 2002; Berger 2004), effects of restored wolves on vegetation communities through trophic cascades (Hebblewhite et al. 2005), and responses of wildlife to the use of prescribed fires all represent problems in understanding how the greater park ecosystem and wildlife populations change over time (Fagre et al. 2003). When you also consider ecosystem responses to climate change, the tasks facing national park scientists in the 21st century seem daunting.

Figure 1 (above). GPS collars (a) provide information that helps park managers determine wildlife-human relationships. GPS collars allow researchers to quantify and correct for habitat-induced GPS bias in a way never possible with VHF data (Hebblewhite et al. 2007). GPS collar studies of carnivores such as (b) wolves provide information on predator-prey relationships, wolf avoidance of human activity, and highway mitigation data (Hebblewhite and Merrill 2008). GPS-collared herbivores such as (c) elk allow park managers to understand links to climate drivers such as phenological changes, predator-prey dynamics, and human interactions (Hebblewhite et al. 2008).

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Remote sensing applications to national parks

Fortunately, new scientific tools based on satellite technology can provide some of the technical data needed to solve these problems. Satellite-based remote sensing of ecosystem dynamics is one of the fastest growing fields in global change research and should become a cornerstone of national park science in the 21st century (Turner et al. 2006). For instance, Pettorelli et al. (2005) provide a recent review of remote sensing tools for ecology that is relevant for park management. Remote sensing will not replace field data collection, but it offers several advantages, including easy implementation of consistent, large-scale, and quantifiable tools to monitor large-scale and long-term changes in park ecosystems (Kerr and Ostrovsky 2003; Zhao et al. 2005). Investigators have used remote sensing in large-scale vegetation–land cover mapping initiatives across park boundaries (Welch et al.1999; Franklin et al. 2005), change detection analysis of century-long trends in vegetation dynamics (Rhemtulla et al. 2002; Stephenson et al. 2006), fire severity mapping (Key and Benson 2003), shrub encroachment (Press et al. 1998), climate change detection (Running et al. 2004; Mildrexler et al. 2007), and glacial recession (Fagre et al. 2003).

But the real advances in understanding the consequences of ecosystem change for wildlife populations are just being realized. Recent studies confirm the importance of changes in remotely sensed measures of primary productivity, vegetation biomass, phytomass blooms in the ocean, snow cover dynamics, and climate to wildlife population dynamics (Huete et al. 2002; Pettorelli et al. 2005; Hebblewhite et al. 2008). The original Landsat satellite provided some of these products for scientists, but improved remote sensing platforms are slowly phasing out and replacing it. For example, the Moderate-resolution Imaging Spectroradiometer (MODIS) satellite circles the globe daily and provides composite images of primary productivity up to every eight days at 250-meter scale resolution (Huete et al. 2002). The main measure of primary productivity, the Normalized Difference Vegetation Index (NDVI), is especially relevant for terrestrial wildlife, although MODIS provides researchers with other useful indexes for measuring ecosystem change (Pettorelli et al. 2005). The NDVI records the reflectance of green plant biomass, including trees, shrubs, forbs, and graminoids, which will allow park scientists to understand the availability of important plant resources for wildlife. Recent technology includes higher-resolution Quickbird satellite imagery at 5-meter resolution for classifying vegetation communities and the astonishingly high resolution 1-meter hyperspectral sensor borne on helicopters, which scientists in Yellowstone National Park have already used (Mirik et al. 2005). Regardless of the new remote sensing tools, the next step will be to link bottom-up measures of primary productivity with wildlife populations. This link is now made easier through another set of technological advances made possible by satellites.

Harnessing knowledge of movement with GPS collar technology

Satellite technology has also brought about the Global Positioning System (GPS) collars that are revolutionizing the field of wildlife research (fig. 1). By locating the collars deployed on wildlife through the GPS system of satellites and either storing the locations onboard or transmitting them back to park scientists, biologists are now poised to understand how animals move in response to their environment. GPS collars are usually deployed for shorter time periods than VHF collars, and many systems have remote data collection technology to allow uploads without disturbing the animal from the ground, air, or satellites. Once the collar has run out of battery power, remote release or timer delay devices allow recovery of the collar without necessitating recapture (although as with any new technology, remote release devices sometimes fail). Remote collar release may also help assuage concerns regarding collaring wildlife in national parks—GPS collars are worn only for short time periods, ensuring collars are not deployed after their utility. Regardless, park managers will surely have to weigh the benefits of GPS collar technology with social perceptions of collars, though for some management questions, there really is no substitute for the data harnessed by this technology. In addition, GPS collars themselves permit researchers to quantify biases in location data for the first time (e.g., Hebblewhite et al. 2007), such as reduced location success under dense cover, improving wildlife habitat modeling for park management.

The real power of GPS collars lies in collection of consistent, fine-scale locations for wildlife ranging in size from elephants to migratory birds (e.g., Weimerskirch et al. 2007); such data collection has already changed how scientists think of park ecosystems.

The movements of a single GPS-collared wolverine as it roamed the entire Greater Yellowstone Ecosystem over a period of months (Inman et al. 2004), and the movements of GPS-collared caribou in the Arctic National Wildlife Refuge (Alaska), confirm key links across park and national boundaries, aiding in conservation (Griffith et al. 2002). The amazing 450-kilometer (280-mi) round-trip migrations of pronghorn in Grand Teton National Park (Wyoming) show that energy development hundreds of kilometers away could influence park wildlife (Berger 2004). In marine systems, GPS collars have tracked migratory albatrosses and sea turtles from marine protected areas throughout entire oceans (James et al. 2005; Weimerskirch et al. 2007). Joint collection of GPS data on predators and their prey is also improving our understanding of predator-prey dynamics and food webs in park ecosystems (Fortin et al. 2005; Forester et al. 2007). GPS locations are especially useful for addressing human-wildlife conflicts in national parks. For example, wolves' avoidance of human activity in daylight in Banff National Park (Alberta, Canada) (Preisler et al. 2006; Hebblewhite and Merrill 2008) was revealed only by GPS collar data. Such fine-scale avoidance of humans may have important implications for wolf-caused trophic cascades (Hebblewhite et al. 2005).

Linking wildlife and ecosystem responses

Significant advances in understanding wildlife responses to ecosystem changes will come from linking data provided by satellite technology with measurement made with GPS collars. For example, in Banff National Park, I developed a linked model of elk migration and vegetation dynamics using GPS-collared migratory elk and remotely sensed, MODIS-derived NDVI data. By working with remote sensing experts at the University of Calgary, our team developed statistical models relating elk migration to changes in biomass and to the quality of subalpine and alpine plant species (Hebblewhite et al. 2008) (fig. 2). These models confirmed that ungulate migration followed the "green" wave of newly emerging forage biomass driven by snowmelt patterns. This helped park managers understand the factors driving declines of migratory elk in this complex, transboundary migratory system (Hebblewhite et al. 2006). However, these kinds of linked wildlife-vegetation systems will also enable park managers to address future impacts of climate change on wildlife in a mechanistic way, improving on simple bioclimatic niche modeling approaches that often simply predict that wildlife will march north as it gets warmer (Post et al. 2009). Because recent studies confirm the critical importance of the spring green-up measured by NDVI to ungulate population dynamics (Pettorelli et al. 2007), understanding changes in the start or duration of the growing season will help clarify probable impacts of climate change on wildlife. Remote sensing provides the platform to collect long-term data to address such changes in key spring phenological parameters. By combining MODIS, Landsat, and earlier sensors, large parts of the world already have 20-year or longer time series of remote sensing data to address these critical questions (Running et al. 2004; Zhao et al. 2005). Furthermore, recent advances that link large-scale climatic indexes such as the North Atlantic Oscillation, Arctic Oscillation, and the El Niño Southern Oscillation with terrestrial primary productivity (Zhang et al. 2007) will help park scientists link wildlife populations to global changes (Hebblewhite 2005; Post et al. 2009).

By combining advances in remote sensing from satellites with satellite-based GPS collar technology, national park scientists will be well poised to understand complex ecosystem-wildlife interactions and apply science-based management in the 21st century.

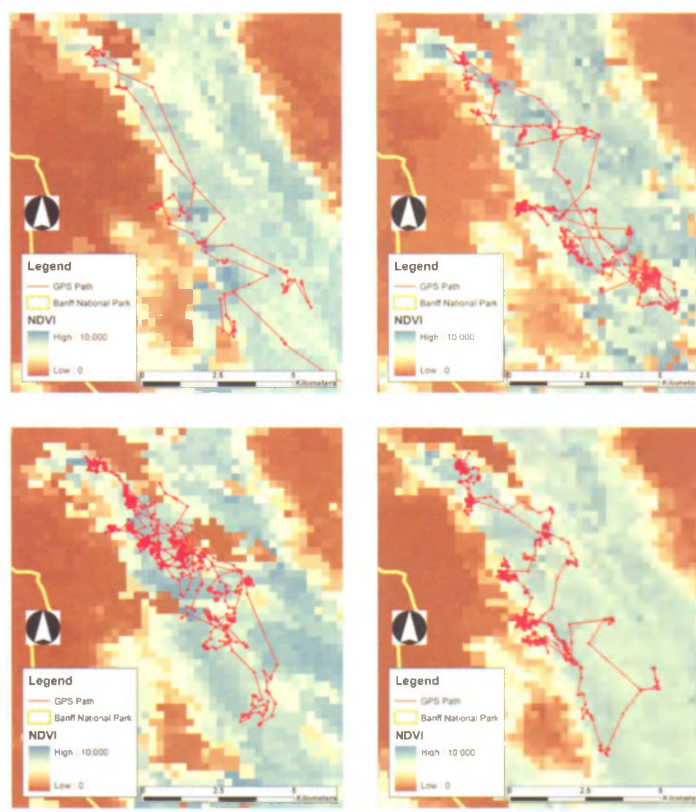

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Figure 2. A Global Positioning System tracks movements of a collared female elk following mountain snowmelt patterns in the Canadian Rocky Mountains. Data show movements following green-up of forage as indexed by the Normalized Difference Vegetation Index (NDVI) from the MODIS satellite in 16-day periods in 2004 from (clockwise from top left) 24 May to 8 June, 9 to 25 June, 26 June to 11 July, and 12 to 27 July 2004.

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About the author

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