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The Human Footprint in the West: A Large-scale Analysis of Human Impacts

Background

Humans have dramatically altered wildlands in the western United States over the past 100 years by using these lands and the resources they provide. Anthropogenic changes to the landscape, such as urban expansion and development of rural areas, influence the number and kinds of plants and wildlife that remain. In addition, western ecosystems are also affected by roads, powerlines, and other networks and land uses necessary to maintain human populations.

The cumulative impacts of human presence and actions on a landscape are called the "human footprint." These impacts may affect plants and wildlife by increasing the number of synanthropic (species that benefit from human activities) bird and mammal predators and facilitating their movements through the landscape or by creating unsuitable habitats. These actions can impact plants and wildlife to such an extent that the persistence of populations or entire species is questionable. For example, greater sage-grouse (*Centrocercus urophasianus*) once were widespread throughout the Great Basin, but now are a focus of conservation concern because populations have declined for the past three decades across most of their range. At the USGS Forest and Rangeland Ecosystem Science Center, we are developing spatial models to better understand potential influences of the human footprint on shrubland ecosystems and associated wildlife in the western United States.

Development of the Human Footprint Map

We are developing the map of the human footprint for the western United States from an analysis of the landscape structure and anthropogenic features. The map focuses on shrubland ecosystems and combines models of habitat use by synanthropic predators ("top-down" effects, see inside right) and the risk of invasive plant presence ("bottom-up" effects, see insight right) to estimate the total influence of human activities. All datasets used in the analysis are archived on the SAGEMAP website (http://sagemap.wr.usgs.gov), maintained by the USGS at the Forest and Rangeland Ecosystem Science Center's Snake River Field Station.

We are modeling human activities that benefit synanthropic predators in order to understand the top-down interaction between predators and shrubland wildlife. For example, power lines are used by common ravens (*Corvus corax*) and raptors for nesting and for hunting perches. Human impacts in rural areas, including agriculture, landfills, and recreational sites, often provide abundant and new food sources which potentially increase the numbers of common ravens, American crows (*Corvus brachyrhynchos*), black-billed magpies (*Pica hudsonia*), brown-headed cowbirds (*Molothrus ater*), and red foxes (*Vulpes vulpes*). Linear features such as railroads, primary and secondary roads, and irrigation channels enhance the movements of predators into previously unused regions (Fig. 1, inside).

black-billed magpie

The spread of invasive plant species often is facilitated along networks of primary and secondary roads, railroads, and power lines. Disturbance associated with creating and maintaining these linear features also enhances the establishment of invasive species. To evaluate these bottom-up effects, we model the risk of exotic plant species invasion along linear corridors (Fig. 2).

We also model anthropogenic factors that interrupt connectivity and increase fragmentation of wildlands, such as roads, railroads, and agricultural lands (Fig.3).

Photo courtesy of Roarke Donnelly

Far left — Amercian crows
Left — common raven

Figure 1
Anthropogenic factors that influence avian predator numbers and habitat use. To model predators' habitat use, we will employ mathematical functions that reflect daily movement patterns of American crows and common ravens.

Left – Urban sprawl in Boise, Idaho.
Below – Irrigation allows cultivation of hay in the high desert of Central Oregon.

Figure 2
Anthropogenic factors that act as dispersal agents for invasive plants. The final model will depict exotic plant invasion risk across landscapes in the western United States.

Above and left – invasive plants trailing along roads.

Figure 3
Anthropogenic factors that influence wildland connectivity and vertebrate dispersal. Our final model will be based on mathematical functions that incorporate inter-patch distance, patch size, and density.

Top-down Versus Bottom-up Effects

An important question in ecology is how food web interactions vary through time and space. Population ecologists and conservation biologists study population dynamics of species by calculating the magnitude and direction of species-specific population growth rates. This measure of population fluctuation is derived from demographic rates such as reproductive, death, and dispersal (the movement of an individual from one to another population), which are affected by factors such as climate, stochastic events (i.e., rare but extreme weather patterns such as severe flooding), predators, parasites, and social structure. Merging the influences of each factor and the complex interactions among them helps population ecologists form hypotheses regarding "top-down" versus "bottom-up" population processes. Top-down (consumer) processes occur when, for example, predators keep prey populations at levels below the population size that would be observed in the absence of predators. On the other hand, if factors such as food and/or habitat availability are the main influences driving population fluctuations, a population is regulated by bottom-up (resource) processes. Populations also can be regulated by both processes, either through a seasonal shift from one process to the other, or when both processes act in concert.

Is a population of a species regulated via top-down or bottom-up processes in an ecosystem of interest? The answer may depend on the ecosystem (e.g., marine versus terrestrial), but it is generally assumed that bottom-up processes are most important in explaining vertebrate population fluctuations. Yet, top-down processes may override bottom-up processes in cases where ecosystems are exposed to atypical disturbance, such as anthropogenic habitat alterations. These anthropogenic factors may affect population size in three ways. They may act top-down by altering habitat or food sources to a degree that allows predator populations to increase and consume more of the species of interest. They may act bottom-up by increasing habitat loss and exploitation to a threshold above which the habitat becomes unsuitable for a given species. Or they may act by altering both top-down and bottom-up processes. Understanding how anthropogenic factors influence the population regulatory processes helps ecologists predict how humans are affecting landscapes and environmental changes.

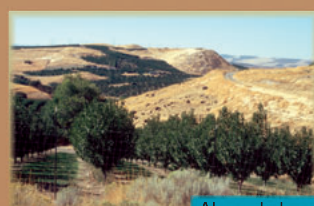
Suggested Readings

Bolger, D. T. 2001. Urban birds: population, community, and landscape approaches. Pages 155-177 *in* Avian Ecology and Conservation in an Urbanizing World (J. M. Marzluff, R. Bowman and R. Donnelly, eds.). Kluwer Academic Publishers, Norwell, MA.

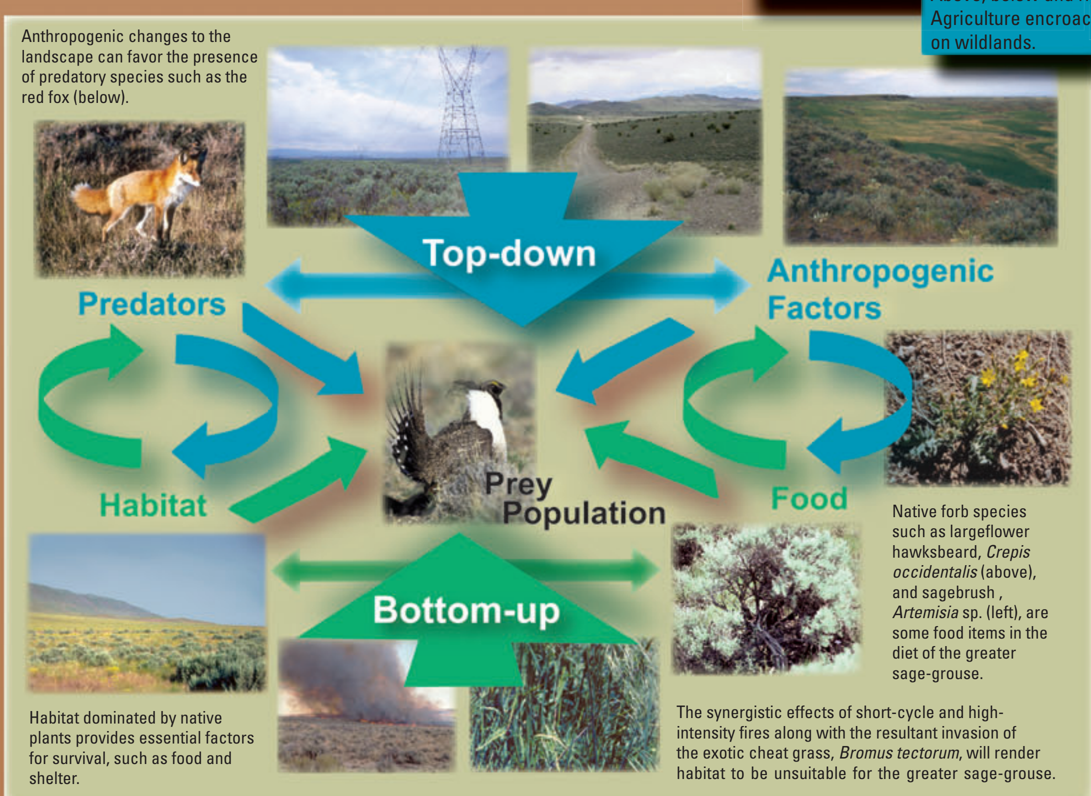
Gratton, C. and R. F. Denno. 2003. Seasonal shift from bottom-up to top-down impact in phytophagous insect populations. Oecologia 134: 487-495.

Sinclair, A. R. E. and J. R. Krebs. 2002. Complex numerical responses to top-down and bottom-up processes in vertebrate populations. Philosophical Transactions of the Royal Society of London, Series B 357: 1221-1231.

Worm, B. and R. Myers. 2003. Meta-analysis of cod-shrimp interactions reveals top-down control of oceanic food webs. Ecology 84: 162-173.



Above, below and right: Agriculture encroachment on wildlands.



This chart depicts the top-down and bottom-up processes, and the interactions among them that potentially affect prey populations. We used the greater sage-grouse to illustrate how anthropogenic factors can influence both top-down and bottom-up processes.

The Human Footprint: Next Steps

Our maps of the human footprint represent preliminary models of the effects of land uses and developments over the western United States. We are planning to test the predictions and associated implications to better understand human influence on shrubland ecosystems in the western United States. Specifically, our next steps include:

- **Testing how predators respond to the human footprint**

Our predictions from the model of synanthropic bird predation risk were substantiated with independent data from the USGS Breeding Bird Survey; however, we need to further test the model with additional surveys of avian as well as mammalian predators.

- **Investigating how species of conservation concern respond to the human footprint**

Greater sage-grouse, Gunnison sage-grouse (*Centrocercus minimus*), and pygmy rabbits (*Brachylagus idahoensis*) are declining in numbers. We need to better understand how the human footprint influences the distribution and abundance of multiple species of concern in shrubland ecosystems. An important component of our analysis is to determine which anthropogenic factors or combination of features may act as barriers to vertebrate movements or dispersal.

Photo courtesy of Mike Gillingham

pgymy rabbit

greater sage-grouse

- **Determining how the population dynamics of wildlife are influenced by the human footprint**

Changes in habitat and predation risk associated with the human footprint may have significant impacts on the ability to maintain wildlife populations. Therefore, we need to assess the relationship between dynamics of wildlife populations and individual and cumulative features of the footprint.

- **Understanding the regional effects of the human footprint on migratory bird populations**

Because many bird species that breed in northwestern shrublands winter in the southwestern United States, we can determine the relative impact of the human footprint on different periods of the annual cycle.

- **Developing models to predict the spread of invasive plants accompanying the human footprint**

Linear features of the footprint provide corridors along which invasive species can spread. Further analysis of the footprint may permit better models that lead to control or slowing invasive species. This is particularly important for shrublands in which the synergistic effects of fire and invasive plants convert ecosystems dominated by native plants to systems dominated by exotic plants.

The Human Footprint: Management and Conservation Implications

The human footprint aids managers in planning, implementing land-use actions, and developing strategies to conserve habitats and wildlife. Modeling the human footprint across large landscapes also allows researchers to generate hypotheses about ecosystem change and to conduct studies in regions differing in potential impact. Because funding for restoration and conservation projects is limited, and because there is little room for errors in the management of species of concern, land managers are able to maximize restoration and conservation efforts in areas minimally influenced by the human footprint. As such, the human footprint model is an important first step toward understanding the synergistic effects acting on shrublands in the western United States.

Credits:

Photos – USGS researchers and the U.S. Fish and Wildlife National Image Library, except as noted.
Graphic Design – Erik Ackerson

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