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Using Remote Sensing Information to Understand Landscape Change

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A key theme of President Obama's recent *Priority Agenda for Enhancing the Climate Resilience of America's Natural Resources* (https://www.whitehouse.gov/sites/default/files/docs/enhancing_climate_resilience_of_americas_natural_resources.pdf) is to "Foster climate-resilient lands and waters" by protecting "important landscapes and developing the science, planning, tools, and practices to sustain and enhance the resilience of the Nation's natural resources."

Migratory Bird Joint Ventures (JVs) and Landscape Conservation Cooperatives (LCCs) are at the forefront of developing such planning and tools to help meet this objective. But they need access to high quality biological and geospatial data to develop the best possible decision support tools to carry out effective conservation. In addition, the ability to monitor biological resources and changes in land cover composition over time is essential to understand the impacts of both our conservation actions and the effects of a changing climate to determine how far we have come towards achieving overarching goals.

"To pursue its mission in the face of complex and persistent challenges, the Fish and Wildlife Service (FWS) has adopted Strategic Habitat Conservation (SHC) as our conservation approach for sustaining populations of fish and wildlife in the context of landscape and system sustainability," said Paul Souza, Assistant Director for Science Applications. "Carrying out SHC involves developing shared, landscape-level, conservation goals, objectives, and strategies based on a scientific understanding of the landscape, including the implications of current and future environmental stressors. Integral to this is the exchange of applied science to carry out conservation strategies with products developed by the LCCs, JVs, and their partners. Remote sensing information is invaluable to this entire process of landscape definition and product development."

JV and LCC science coordinators have cultivated extensive networks of ecologists whose research may emphasize particular species or vegetative communities. However, most JVs and LCCs have not developed the same network of remote sensing

Continued next page

Inside this issue:

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scientists who can be relied upon to provide insight into the availability and use of geospatial data. To address this concern and help the JVs and LCCs develop tools and datasets necessary to achieve their missions, a one-day symposium was organized to facilitate discussion among these two groups of scientists.

In this issue of *The All Bird Bulletin*, we recap the presentations and ensuing discussions from the *Symposium to Advance the Integration of Remote Sensing Technology into Habitat Conservation Planning Tools*, held during the *National Workshop on Large Landscape Conservation* in Washington, D.C., in October 2014. The purpose of the symposium was to bring together conservation biologists and remote sensing scientists to discuss how remote sensing data are being used and can be used, and what we'd like to accomplish through future collaborations for conservation.

Remote Sensing Technologies. Advances in remote sensing technologies, and the availability of faster computers with larger and larger amounts of storage, have provided landscape ecologists and planners with powerful tools to spatially organize conservation objectives. The land cover maps derived from these technologies are based on the physical properties of the electromagnetic spectrum (EMS) and how different surface features reflect and absorb the sun's energy. The difference in reflectance of different surface features is what allows us to produce land cover maps. Remote sensing sensors can be classified by how they measure these differences. Is the sensor airborne or space-borne? Is it passive, where it measures reflected energy from the sun, or active, where the sensor itself emits energy and measures the reflectance of that energy?

The imagery provided by the different satellite sensors can be characterized by four types of resolution. These include: (1) spectral resolution, the number and width of the different wavelength bands the reflected energy is divided into; (2) spatial resolution, the area on the ground that each pixel represents; (3) temporal resolution, the length of time between repeated measurements of the same area on the earth's surface; and (4) radiometric resolution, the smallest "slice" of a band or portion of the EMS in which the reflectance of a feature may be assigned a digital number (i.e., the sensitivity of the sensor expressed in differences in EMS signal strength.)

In the article on Page 4, the authors summarize remote sensing data and sensors, provide links to informational web sites, and review some of the most commonly used remote sensing sensors and their technical specifications, along with a few of the various land cover dataset products available to conservation partners.

The Importance of Remote Sensing Information to Conservation. Presenters kicked off the fall 2014 symposium in Washington, D.C., with two talks that provided background on the types of biological planning models and tools that the JVs and LCCs have developed to provide decision support for conservation delivery and the importance of remote sensing information to their development.

For example, setting quantitative population objectives is a core component of SHC, and decision support tools are developed with achieving these objectives in mind. But the critical question remains: Is it even possible to meet those goals given current amounts of habitat and rates of loss?

The Prairie Pothole Joint Venture set out to answer that question (Doherty et al. 2013 [doi: 10.1002/wsb.284]) and determined that under current rates of prairie loss—1.3 percent per year—and conservation—0.26 percent per year—the objectives set by the JV cannot be met. In fact, even if current rates of loss are cut by two thirds and rates of conservation are doubled, the population goals cannot be met given the amount of available habitat on the landscape. The JV is currently updating their implementation plan and will be using a different approach to set short-term five-year habitat and population objectives due in part to these results; the current objectives will be retained as long-term and aspirational. This work by the PPJV illustrates the importance of information on habitat availability and loss rates to the process of setting realistic and achievable goals. Without question, having access to accurate, high quality geospatial data is invaluable to this process.

A second example is the implementation of Habitat Suitability Index (HSI) models. HSI models are useful tools to understand how individual factors interact to define suitable habitat for particular species. Applying these models to geospatial datasets that characterize these individual factors provides a depiction of the distribution of suita-

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ble habitat across the landscape, which is used to target habitat conservation. The Alligator Gar is a priority species for the Gulf Coastal Plains and Ozarks LCC that is assumed to be limited primarily by spawning habitat that occurs in the floodplain along big rivers. GCPO partners are interested in developing conservation options for this species, and by applying multiple spatial datasets to effectively describe spawning habitat, they were able to not only identify where adequate spawning habitat currently existed but also what factors were deficient where it didn't. The result was an HSI model that ranks priority conservation areas for spawning habitat on the landscape as well as provides insight into restoration options.

Finally, LCCs have collectively agreed to use a landscape conservation design process to complete their planning. Landscape conservation design is rooted in the science of landscape ecology—specifically the premise that the ecological value of individual acres varies with their landscape context. Landscape conservation design involves using information on the socio-ecological processes active on the landscape to develop and spatially depict conservation strategies to address these active processes and achieve specific conservation targets.

An example of a human-driven process on the landscape is agriculture. With the help of scientists at The Nature Conservancy in Wyoming, staff at the Playa Lakes Joint Venture used a model created by TNC to predict the likelihood of a parcel of land to be tilled. The premise of the model is that the probability of land being tilled in the future is related to the characteristics (e.g., soil types, precipitation, etc.) of land that has been tilled in the past. Each pixel is assigned a probability, which can help guide bird habitat conservation. For example, a field that is currently in native habitat but with high tillage likelihood could be targeted for a conservation easement program. On the other hand, a field that is currently tilled but is identified in the model as a low tillage probability could be targeted for a grassland restoration program like Conservation Reserve Program.

Articles on pages 9 through 27 in this edition of the *ABB* present additional case studies of how partners are using geospatial data in unique and cutting-edge ways to answer pressing conservation questions. For example, in the article on Page 9, the authors discuss the collaboration between the National Gap Analysis Program (GAP) and the Landscape Fire and Resource Management Planning Tools Program (LANDFIRE) to update and significantly refine these two geospatial land cover products used by conservation biologists all over the country.

Authors of the article on Page 13 discuss some cutting-edge methods for using Landsat data to model land cover, and describe their work to improve land cover data using Landsat imagery. They track the reflective signatures at the individual pixel level to determine land cover class, and track changes due to disturbances such as wildfire and successional changes in vegetation. In addition, the authors describe their work fore- and back-casting land cover using their Forecasting Scenarios of Land Use Change (FORE-SCE) models, and their efforts to make a publicly available version of these models so that conservation organizations can model land cover for their specific needs.

In the article on Page 18, the author discusses the use of Landsat imagery to detect changes in the amount of Water Hyacinth in the Sacramento-San Joaquin River Delta of California. The Delta provides critical wintering habitat for many migratory wetland birds and these data can help managers target areas for treatment of Water Hyacinth.

In the article on Page 21, the authors discuss the novel idea of using bird data to inform land cover modeling. The authors used unclassified Landsat imagery to create species distribution models of oak-woodland dependent species. Using species richness values of individual pixels, the authors then classified the pixels as oak woodlands, creating highly accurate maps of oak woodland habitat for bird habitat conservation planning and delivery.

Finally, in our concluding article on Page 24, we summarize what was learned in the course of the fall 2014 symposium on integrating remote sensing data into habitat conservation planning tools. Most importantly, we discuss next steps for conservation practitioners to access and use these important datasets, and how conservation scientists and remote sensing experts can work together to create, improve, and build on existing programs and datasets. Such efforts are imperative to developing habitat conservation planning tools and strategies that can help sustain wildlife populations for future generations. Read on and consider how you too can get involved in these cutting edge collaborations for conservation.

Remote Sensing Data and Product Resources for Conservation

Duane B. Pool, Landscape Ecologist, Rocky Mountain Bird Observatory and Mark W. Parr, Remote Sensing/Geographic Information System Analyst, Gulf Coast Joint Venture

Remote sensing tools and technology play an important role in helping Migratory Bird Joint Ventures (JVs) and Landscape Conservation Cooperatives (LCCs) achieve specific objectives related to spatial prioritization of conservation opportunities. This is primarily reflected in the importance of land cover datasets in determining these spatial priorities and the application of remote sensing tools and other geospatial technologies to create these datasets.

We provide below:

1. A set of resource tables on where to find out more about the most common sources of remotely sensed data;
2. The spatial, spectral, and temporal resolution of the source data;
3. A list of the information on several products derived from remotely sensed data that may be useful to conservation planning;
4. A description of the spectral bands from the Landsat 8 Operational Land Imager (OLI) and the Moderate-resolution Imaging Spectroradiometer (MODIS) Sensor System;
5. Examples of potential targets each band may help identify or quantify; and
6. A resource article from the *Journal of Applied Ecology* that provides examples of what sensors or platforms were used to accomplish a variety of ecological studies.

In short, we summarize remote sensing data and sensors, list information web sites, review some of the most commonly used remote sensing sensors and their technical specifications along with a few of the various products available to JVs and LCCs in terms of land cover datasets. Finally we reference a meta-analysis with some real life applications of remotely sensed data and associated technology.

Many remote sensing scientists use a handful of websites on a regular basis for access to and information about available data. NASA is responsible for many of the U.S. satellites, and the U.S. Geological Survey maintains data access and archive sites for the digital data that is transmitted back down to Earth. The primary download sites for remotely sensed data maintained by the U.S. Geological Survey are serviced through their Earth Explorer and Global Visualizer sites (see Table 1). Information on specific sensors can be found at each provider's supported page. In addition, the University of Twente in New Zealand has a series of resource pages on both Sensors (i.e. Enhanced Thematic Mapper [ETM]) and Platforms (i.e. Landsat) if the information you need is not included in the list of common providers in Table 1 below.

Table 1. Key Websites

USGS data access	http://earthexplorer.usgs.gov/
	http://glovis.usgs.gov/
NASA	http://reverb.echo.nasa.gov
University of Twente - Sensor and Platform information	http://www.itc.nl/research/products/sensordb/allsensors.aspx
MODIS	https://lpdaac.usgs.gov
Landsat	http://landsat.usgs.gov/index.php
SPOT	http://www.geo-airbusds.com
Digital Globe	http://www.digitalglobe.com
NAIP	http://datagateway.nrcs.usda.gov

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Understanding the resolution of the data required for your specific biological application is your primary guidance for selecting the best remotely sensed data for your project. As a rule of thumb, the spatial resolution of the data you need for biologically meaningful application should be at least one-half the size of the smallest element you are attempting to detect. Spectral resolution narrows which wavelengths will respond to on-the-ground features you are attempting to differentiate. If you are expecting to see changes in your features over time such as phenology studies, or if you need multiple images over the same area as your observation window for detecting changes in wet area or vegetative condition, then the length of time between revisits or temporal resolution may be important to your selection. Several of the most common satellite systems provide a range of information at different resolutions. In Table 2, we provide examples for several common systems.

Table 2.

Platform/Sensor		Spatial Resolution (m) p = panchromatic	Spectral range (µm)	Revisit Interval (days)
MODIS		250 to 1000		1, 8, 16, 30, 90, 365
	Terra		0.405 to 2.155	
	Aqua		3.660 to 14.385	
Landsat		15p, and 30-80	0.45 to 2.35	16
SPOT		2.5p and 10	0.50 to 1.75	5
IRS		5p, and 23.5-70.5	0.50 to 1.70	5
Ikonos		1p and 4	0.45 to 0.85	3
Quickbird		0.61p and 2.44	0.45 to 0.90	3
FORMOSAT		2p and 8	0.45 to 0.90	1
Worldview		0.46p and 1.8	0.40 to 1.04	1.1
ALOS		2.5p and 10	0.42 to 0.89	2
Geoeye		0.41p and 1.65	0.45 to 0.90	3

If the creation of custom datasets or the direct use of raw remotely sensed data are not required for your project, there are still a variety of off-the-shelf value added classification products available for many planning and research purposes (see Table 3). Several federal and state agencies have contributed to, developed, and maintained a variety of land cover products. These include high altitude photography, orthographic imagery, generalized national land cover datasets, more refined state and regional Gap Analysis Program data, forest inventories, and a large variety of physical and vegetative features used for forest fire mitigation and response. These common products may already capture some or all of the information you need. Keep in mind that each of these programs wants you to use their data so that they can demonstrate the added value of their efforts beyond the scope of their specific user base.

The Landsat 8 satellite consists of two sensors: the Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS; see Table 4). While the TIRS is useful for measuring surface temperature, the OLI is the primary Landsat sensor used in land cover mapping applications. The OLI consists of nine spectral bands with a spatial resolution of 30 meters (Bands 1 to 7, and Band 9). Band 8, the panchromatic band, has a spatial resolution of 15 meters. Each scene is available for free download within 24 hours of acquisition and is approximately 170km x 183km in size.

The USGS MODIS platform was designed for moderate spatial resolution use. It has the benefit of a wide variety of spectra that are captured by the instruments. Each spectral range for MODIS has some known potential applications, which are summarized in the Table 5.

Finally there are many examples of research that use remotely sensed data and classified data for analysis and guidance in conservation and ecological science (see citations on Page 11). Most recently Pettorelli et al. (2014) provided an overview of what has been done to apply remote sensing to environmental issues (see Table on Page 12).

For more information, contact Duane Pool at duane.pool@rmbo.org or Mark Parr at mparr@gcjv.org.

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Table 3.

Products	Spatial Resolution	Spectra , or Data Layers	Additional Information	Program Website, Acronym Name, Reference
Various			Links to map services for HRO, NAIP, NLCD	http://cumulus.cr.usgs.gov/services.php
HRO	.25 to 2.5 ft	Panchromatic, Red, Green, Blue, Near Infrared		High Resolution Orthoimagery
NAIP	1m	Red, Green, Blue, Near Infrared		National Agriculture Imagery Program
NLCD 2011	30m			National Land Cover Database 2011 (additional years available)
NLCD IS	30m			Impervious Surface - percent developed imperviousness
NLCD TC	30m			Tree Canopy - percent tree canopy cover
GAP	30m		8 - 590 land use classes with 1 acre Minimum Mapping Unit (MMU)	http://gapanalysis.usgs.gov/gaplandcover/data/
				Terrestrial Ecological Systems Classification framework (Comer et al. 2003)
LandFire	30m	Fuel Models	Primary use for fuel models and vegetation change including temporal tracking of disturbance. Revisit ~2 years (2001, 2008, 2010, 2012)	http://www.landfire.gov/data_overviews.php
		Environmental Site Potential		
		Biophysical Settings (Pre-European conditions)		Terrestrial Ecological Systems Classification framework (Comer et al. 2003)
		Existing Vegetation Type (EVT)		
		Existing Vegetation Height (EVH)		average height of the dominant vegetation for a 30-m grid cell
		Existing Vegetation Cover (ECV)		vertically projected percent cover of the live canopy layer for a 30-m grid cell
		Vegetation dynamics models		State and transitions models
		Anderson Fire Behavior Fuel Models (FBFM13)		Rothermel 1972
		Scott and Burgan Fire Behavior		Scott and Burgan (2005)
		Canadian Forest Fire Danger		
		Canopy Bulk Density (CBD)		mass of available canopy fuel per canopy volume unit
		Canopy Base Height (CBH)		average height from the ground to a forest stand's canopy bottom
		Forest Canopy Height (CH)		average height of the top of the vegetated canopy
		Forest Canopy Cover (CC)		percent cover of the tree canopy
		Vegetation Condition Class /Vegetation Departure Index (VCC/VDEP)		amount that current vegetation has departed from the simulated historical vegetation reference conditions
		Elevation		
		Aspect		
		Slope		
GFCI		Global Forest Change Initiatives		www.globalforestwatch.org
				www.forestcover.org

Table 4.

Landsat 8 OLI and TIRS

Bands	Wavelength (µm)	Resolution (m)
Band 1 - Coastal aerosol	0.43-0.45	30
Band 2 - Blue	0.45-0.51	30
Band 3 - Green	0.53-0.59	30
Band 4 - Red	0.64-0.67	30
Band 5 - Near infrared (NIR)	0.85-0.88	30
Band 6 - SWIR 1	1.57-1.65	30
Band 7 - SWIR 2	2.11-2.29	30
Band 8 - Panchromatic	0.50-0.68	15
Band 9 - Cirrus	1.36-1.38	30
Band 10 - TIRS 1	10.60-11.19	100 *
Band 11 - TIRS 2	11.50-12.51	100 *

* TIRS data is acquired at 100m resolution, but are resampled to 30m in delivered data product

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Table 5.
Common uses for SPECTRAL ranges with key to MODIS Band numbers.

BAND #	RANGE nm	RANGE um	KEY USE
	Reflected	Emitted	
1	620–670		Absolute Land Cover Transformation/ Vegetation Chlorophyll
2	841–876		Cloud Amount/ Vegetation Land Cover Transformation
3	459–479		Soil/Vegetation Differences
4	545–565		Green Vegetation
5	1230–1250		Leaf/Canopy Differences
6	1628–1652		Snow/Cloud Differences
7	2105–2155		Cloud Properties/Land Properties
8	405–420		Chlorophyll
9	438–448		Chlorophyll
10	483–493		Chlorophyll
11	526–536		Chlorophyll
12	546–556		Sediments
13h	662–672		Atmosphere/Sediments
13l	662–672		Atmosphere/Sediments
14h	673–683		Chlorophyll Fluorescence
14l	673–683		Chlorophyll Fluorescence
15	743–753		Aerosol Properties
16	862–877		Aerosol Properties/Atmospheric Properties
17	890–920		Atmospheric Properties/Cloud Properties
18	931–941		Atmospheric Properties/Cloud Properties
19	915–965		Atmospheric Properties/Cloud Properties
20		3.660–3.840	Sea Surface Temperature
21		3.929–3.989	Forest Fires & Volcanoes
22		3.929–3.989	Cloud Temperature/Surface Temperature
23		4.020–4.080	Cloud Temperature/Surface Temperature
24		4.433–4.498	Cloud Fraction/Troposphere Temperature
25		4.482–4.549	Cloud Fraction/Troposphere Temperature
26		1360–1390	Cloud Fraction (Thin Cirrus)/Troposphere Temperature
27		6.535–6.895	Mid Troposphere Humidity
28		7.175–7.475	Upper Troposphere Humidity
29		8.400–8.700	Surface Temperature
30		9.580–9.880	Total Ozone
31		10.780–11.280	Cloud Temperature/Forest Fires & Volcanoes/Surface Temp.
32		11.770–12.270	Cloud Height/Forest Fires & Volcanoes/Surface Temperature
33		13.185–13.485	Cloud Fraction/Cloud Height
34		13.485–13.785	Cloud Fraction/Cloud Height
35		13.785–14.085	Cloud Fraction/Cloud Height
36		14.085–14.385	Cloud Fraction/Cloud Height

Some examples of conservation and ecological science research that use remotely sensed data and informs data classifications:

Comer, P., D. Faber-Langendoen, R. Evans, S. Gawler, C. Josse, G. Kittel, S. Menard, M. Pyne, M. Reid, K. Schulz, K. Snow, and J. Teague. 2003. Ecological Systems of the United States: A Working Classification of U.S. Terrestrial Systems. NatureServe, Arlington, Virginia.

Rothermel, Richard C. 1972. A mathematical model for predicting fire spread in wildland fuels. Res. Pap. INT-115. Ogden, UT: U.S. Department of Agriculture, Intermountain Forest and Range Experiment Station. 40 p.

Scott, Joe H.; Burgan, Robert E. 2005. Standard fire behavior fuel models: a comprehensive set for use with Rothermel''s surface fire spread model. Gen. Tech. Rep. RMRS-GTR-153. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 72 p.

Stocks, Brian J.; Lawson, Bruce D.; Alexander, Martin E.; Van Wagner, C.E.; McAlpine, Rob S.; Lynham, Timothy J.; Dube, Dennis E. 1989. The Canadian Forest Fire Danger Rating System: an overview. The Forestry Chronicle 65(6):450-457.

Pettorelli, Nathalie; Laurance, William F.; O'Brien, Timothy G.; Wegmann, Martin; Nagendra, Harini; Turner, Woody. 2014. Satellite remote sensing for applied ecologists: opportunities and challenges. Journal of Applied Ecology 51(4): 1365-2664. DOI - http://dx.doi.org/10.1111/1365-2664.12261

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REVIEW

Satellite remote sensing for applied ecologists: opportunities and challenges

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Table 1. Non-exhaustive list of examples illustrating how SRS can be used to tackle environmental challenges

Environmental challenge	Sensor	Reference
Species distribution mapping	ETM+ and Quickbird	Fretwell *et al.* (2012)
Invasive species detection	TM & ETM+	Bradley & Mustard (2006)
Invasive species detection	IKONOS	Fuller (2005)
Invasive species detection	Hyperion	Pengra, Johnston & Loveland (2007)
Migration route prediction	AVHRR	Boone, Thirgood & Hopcraft (2006)
Informing reintroductions	AVHRR	Freemantle *et al.* (2013)
Overgrazed areas mapping	AVHRR	Otterman *et al.* (2002)
Mangrove coastal retreat monitoring	PALSAR	Cornforth *et al.* (2013)
Fire monitoring	MODIS	Justice *et al.* (2002)
Assessing fire risk	AVHRR	Maselli *et al.* (2003)
Drought probability assessment	AVHRR	Rojas, Vrieling & Rembold (2011)
Flood monitoring, mapping and management	RADARSAT	Hoque *et al.* (2011)
Oil slick detection and monitoring	RADARSAT, MODIS, AVHRR	Klemas (2010)
Air quality assessment	GOME-2, MODIS & MOPITT	Hao *et al.* (2011)
Insect-induced defoliation mapping	MODIS	Eklundh, Johansson & Solberg (2009)
Land cover change monitoring	TM, ETM, ETM+	Hansen & Loveland (2012)
Deforestation	MODIS & ETM+	Briant, Gond & Laurance (2010)
Habitat fragmentation	TM	Heilman *et al.* (2002)
Land degradation	AVHRR	Prince, Becker-Reshef & Rishmawi (2009)
Forest degradation mapping	MODIS	Garonna *et al.* (2009)
Forest degradation mapping	HRG	Souza *et al.* 2003
Urbanization tracking	DMSP/OLS	Zhang & Seto (2011)
Urbanization tracking	SAR	Taubenbock *et al.* (2012)
Natural resource extraction detection	ETM+	Duncan *et al.* (2014)
Natural resource extraction detection	ATSR	Casadio, Arino & Serpe (2011)
Tracking the effect of climate change on ecosystem functioning	AVHRR	Pettorelli *et al.* (2012)
Carbon stock mapping	GLAS, MODIS, SRTM, QSCAT	Saatchi *et al.* (2011)
SRS-based platform for the global monitoring of protected areas	MODIS, HRG, Landsat	Dubois *et al.* (2011)

ATSR, Along Track Scanning Radiometer; AVHRR, Advanced Very High Resolution Radiometer; DMSP/OLS, U.S Air Force Defense Meteorological Satellites Program/Operational Linescan System; (E)TM, (Enhanced) Thematic Mapper; GLAS, Geoscience Laser Altimeter System; GOME-2, Global Ozone Monitoring Experiment 2; HRG, high-resolution geometrical; MODIS, Moderate-Resolution Imaging Spectroradiometer; MOPITT, Terra's Measurements of Pollutants in the Troposphere; PALSAR, Phased Array type L-band Synthetic Aperture Radar; QSCAT, Quick Scatterometer; SAR, Synthetic Aperture Radar; SRTM, Shuttle Radar Topography Mission.

Pettorelli, Nathalie; Laurance, William F.; O'Brien, Timothy G.; Wegmann, Martin; Nagendra, Harini; Turner, Woody. 2014. Satellite remote sensing for applied ecologists: opportunities and challenges. Journal *of Applied Ecology* 51(4): 1365-2664. DOI (http://dx.doi.org/10.1111/1365-2664.12261)

Coming Together for an All-Lands Dataset to Support Wildfire and Wildlife Conservation Planning

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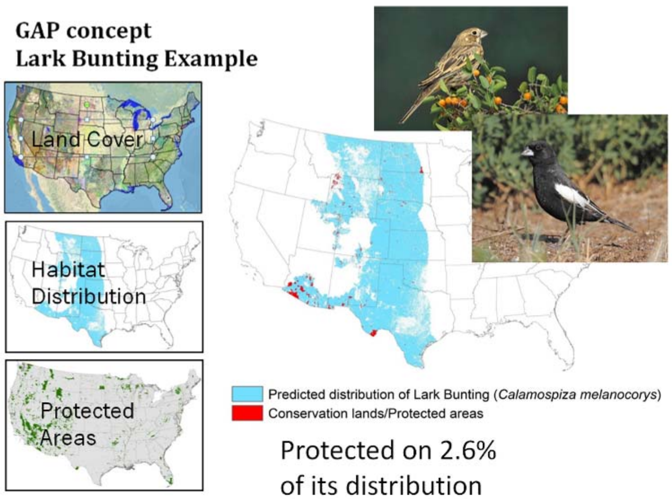

Figure 1. Example of a gap analysis for a single species. In order to quantify the representation of a species' habitat in the current conservation network, the Protected Areas Database is intersected with the modeled habitat distribution. In this case 2.6 percent of the Lark Bunting habitat occurs in lands that are permanently protected and managed primarily for biodiversity (Status 1 and 2 lands). Photo credits: Female, Rick and Nora Bowers; Male, Terry and Joanne Johnson.

Introduction. The National Gap Analysis (GAP) and Landscape Fire and Resource Management Planning Tools (LANDFIRE) Programs are teaming up to deliver detailed land cover maps that support wildland fire and species conservation planning for the nation. Advances in remote sensing have resulted in the recent development of these thematically rich land cover maps (more than 500 map classes for the U.S.) based on the Ecological Systems Classification (Comer et al. 2003) with a necessary emphasis on natural and semi-natural vegetation. While historically these programs worked independently, they are now collaborating to define the map legend and technical requirements for a 2016 remap of the U.S. based on newly launched Landsat Operational Land Imagery (OLI) imagery. The complete remap of the U.S. vegetation to 2016 conditions is projected to be completed by 2019. The collaboration is a natural evolution of these two programs, which are coming together to create the core land cover datasets needed to meet each of their needs.

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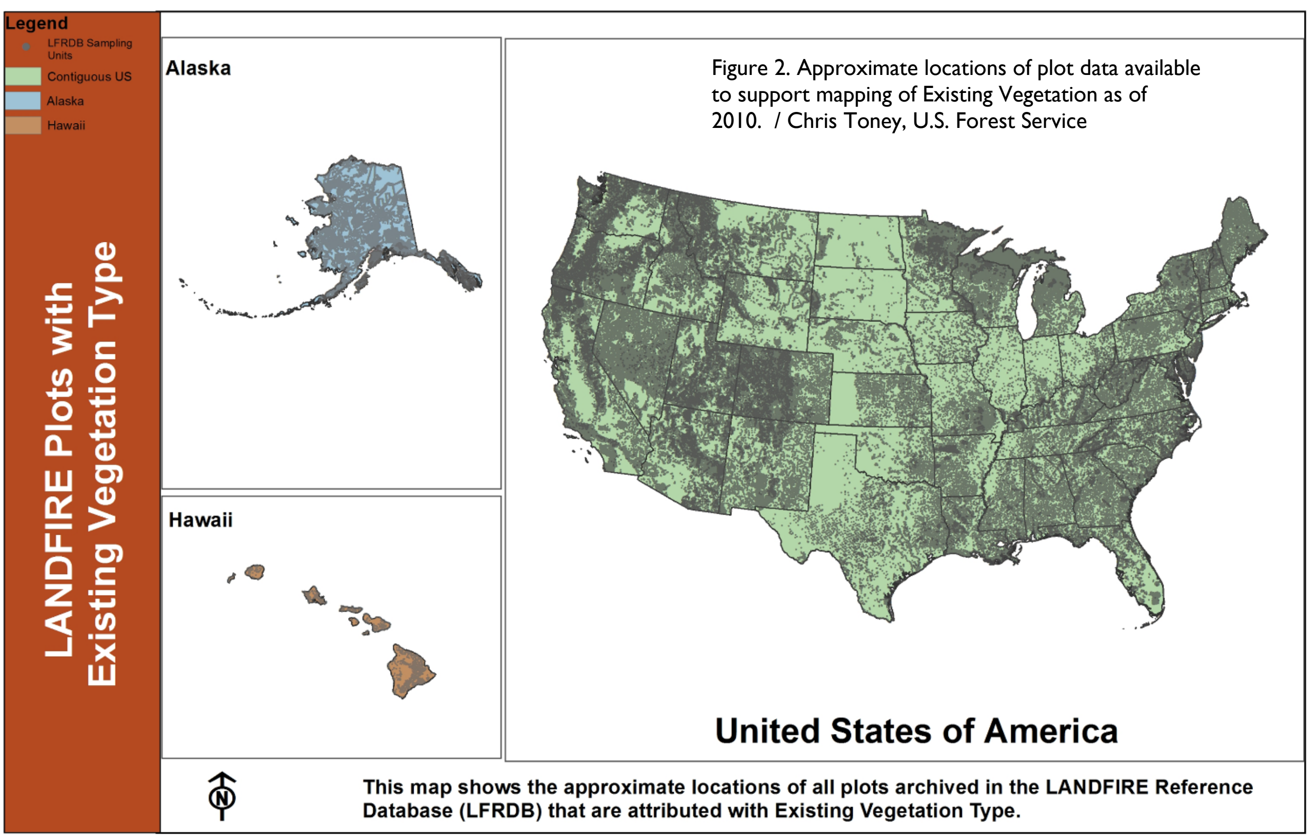

Figure 2. Approximate locations of plot data available to support mapping of Existing Vegetation as of 2010. / Chris Toney, U.S. Forest Service

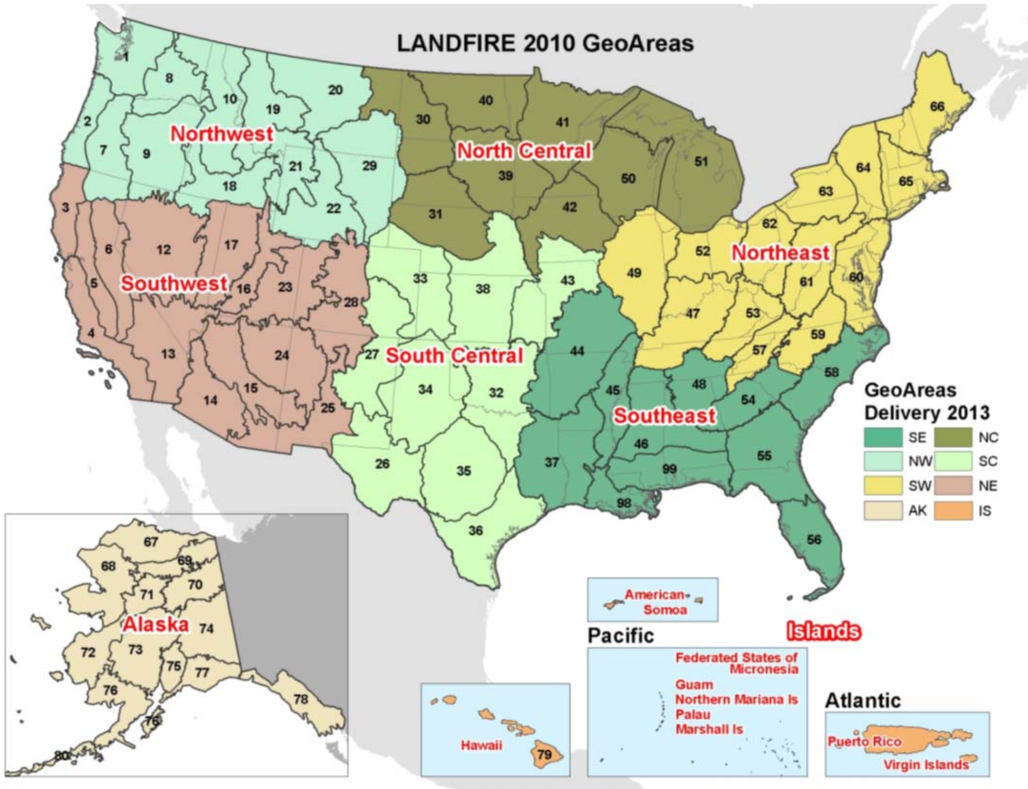

Figure 3. Map of the geographic framework (Map Zones and Regional GeoAreas) that the LANDFIRE Program utilizes in production and delivery processes.

Background. GAP's mission is to provide data and analytical tools to resource managers and policy makers with the aim of keeping common species common. To meet this mission three core datasets are created, including a detailed land cover/vegetation map, the Protected Areas Database of the U.S., and species distribution models for every native terrestrial vertebrate species in the U.S. Identifying gaps involves a spatial overlay of the protected areas and the species habitat or plant community distribution of interest (see Figure 1 for example of GAP analysis for Lark Bunting).

LANDFIRE's mission is to provide agency leaders and managers with a common "all-lands" data set of vegetation and wildland fire/fuels information and related tools that support strategic fire and resource management planning and analysis. The program achieves this by creating and periodically updating comprehensive vegetation, fire and fuel characteristics data using a consistent process for the U.S., including Alaska and Hawai'i. The detailed land cover dataset, Existing Vegetation, is just one of the over 20 geospatial datasets LANDFIRE generates to support their wildland fire planning.

LANDFIRE's Land Cover Mapping Methods. Mapping of the existing vegetation data is a decision tree process based upon an extensive plot database, the LANDFIRE Reference Database (LFRDB), derived ancillary datasets, and multi-date Landsat imagery mosaics. At last count, data for over 800,000 plots from a variety of agencies had been gathered to support the mapping (see Figure 2). The LANDFIRE Existing Vegetation Data Layer was developed in 2001, and has been updated on a biennial basis by identifying disturbance (e.g. fire, insect, harvest) and updating the description of vegetation in the areas that had been disturbed. Figure 3 shows the geographic framework used to produce the disturbance datasets and to update the 2001 vegetation map to reflect 2010 and 2012. Delivery of the updated 2014 conditions is expected in 2016.

Species Modeling. GAP develops deductive habitat distribution models using the scientific literature. The first step in the process involves creating seasonal range maps for each species based on subwatersheds (12 digit hydrologic units) in the Watershed Boundary Dataset. Species distribution models are built using a national wildlife

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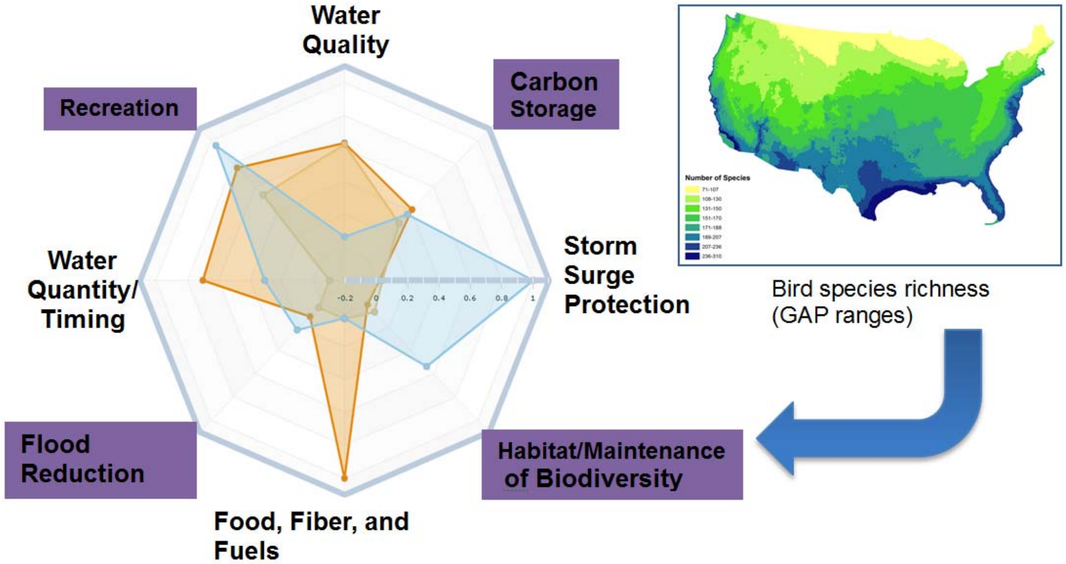

Figure 4. Environmental Protection Agency's National Atlas of Ecosystem Services. The radar chart on the left provides a visual comparison of the relative provisioning of ecological services of two sites. In this example, three sites are being considered (blue, light tan, and tan). Each axis shows a specific ecosystem service being measured on a scale from 0 to 1. The site represented in blue ranks higher in provision of storm surge protection, habitat/maintenance of biodiversity, and recreation. Species Richness Maps from the National Gap Analysis Program are used to quantify the contribution to habitat and maintaining biological diversity.

habitat relational database (WHRD) based on habitat associations described in published literature. The models are created at 30-meter resolution using a suite of environmental datasets, including detailed land cover, elevation, and hydrological characteristics (e.g., salinity, water type, and velocity).

Currently 1,409 species distribution models have been completed (89 amphibians, 681 birds, 332 mammals, and 307 reptiles), including all native birds and reptiles for the U.S. Species ranges and models can be viewed online, accessed through web services, or downloaded (http://gapanalysis.usgs.gov/species/viewer/). Our goal is to complete the remaining mammal (105) and amphibian (235) models and conduct the national gap analysis for all species in the coming year. When the 2016 Land Cover Remap described on Page 9 is available, the models will be updated to reflect the current conditions.

Applications. The availability of the national land cover and species habitat models being developed by GAP and LANDFIRE has led to a variety of innovative uses beyond the original analyses designed to meet the specific needs of the programs themselves. Below is a list of some of the products that have resulted from the application of GAP and LANDFIRE.

GAP Applications. GAP data have been used to assess species' current conservation status, as well as in exploring the potential impacts of land use and climate change scenarios on species, their habitats, and plant communities. While GAP works to provide data on all native terrestrial vertebrates, the analysis specific to birds reflects the relative wealth of information available for those taxa.

State of the Birds. The U.S. North American Bird Conservation Initiative (NABCI) Committee used GAP's Protected Areas Database and land cover datasets to analyze the patterns of bird distributions specific to public and private lands, as well as to characterize habitat indicators for birds in steep decline in their recent *State of the Birds* report series (NABCI 2011, 2013, 2014).

Environmental Protection Agencies National Atlas of Sustainability. Boykin et al. (2013) used the GAP species models to develop species richness maps used to quantify biodiversity metrics at multiple spatial scales in EPA's EnviroAtlas (see Figure 4).

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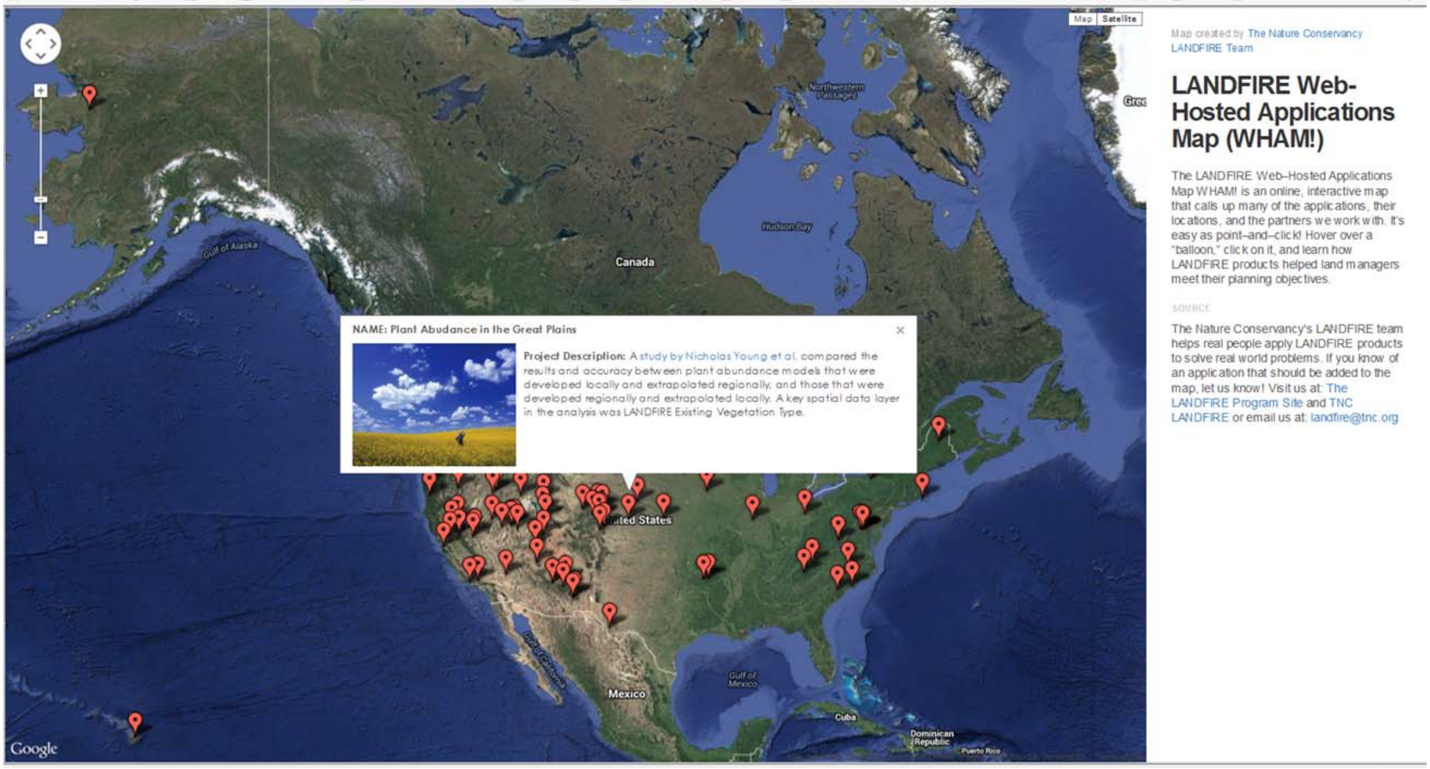

Figure 5. LANDFIRE's Web-Hosted Applications Map (WHAM!). This interactive web application provides details on a wide diversity of projects that have used the LANDFIRE datasets to address natural resource questions across the country (maps.tnc.org/landfire).

Longleaf Pine Ecosystem. Costanza et al. (2015) used the GAP land cover and Ecological System specific vegetation dynamics models developed by LANDFIRE to assess the potential impact of climate and urbanization on the longleaf pine ecosystem in the southeastern U.S.

Future Land Use Scenarios in the Southeastern U.S. Martinuzzi et al. (2015) used the GAP's species habitat distribution models in combination with land use scenarios to assess the potential impact of conservation and agricultural policies on habitat loss.

LANDFIRE Applications. LANDFIRE has been applied extensively in both fire and non-fire arenas. We highlight a few below that are directly related to avian species or populations. Learn more about these and other applications on the LANDFIRE Web-Hosted Applications Map (maps.tnc.org/landfire; see Figure 5).

Northern Goshawk. Bruggeman et al. (2014) used LANDFIRE 2008 Succession Class, Canopy Total Height, and Canopy Base Height 30-meter raster spatial products to evaluate landscape use by Northern Goshawk. The authors used an information-theoretic approach, a data-based selection of the best supported of many competing statistical models, to evaluate hypotheses regarding which factors were most related to the probability of Northern Goshawk landscape use.

Avian Habitat Availability. Nixon et al (2014) used LANDFIRE Vegetation Dynamics Models and other datasets to evaluate the impacts on habitat availability over 100 years of four alternative conservation strategies in a 50,000+-hectare landscape in Michigan's Upper Peninsula. The five target bird species of local conservation concern are Blackburnian Warbler, Black-backed Woodpecker, Kirtland's Warbler, Red-shouldered Hawk, and American Woodcock.

Woodpeckers. LANDFIRE Canopy Cover and Canopy Height spatial products were used with other datasets in a study that assessed the distribution and area of occupancy for Pileated Woodpecker and American Three-toed Woodpecker in north-central Idaho. Baumgardt et al. 2014 also compared occupancy estimates

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Using Landsat Imagery to Detect, Monitor, and Project Net Landscape Change

Ryan Reker, Geographer, Arctic Slope Regional Corporation Federal InuTeq, and Terry Sohl, Research Physical Scientist, and Alisa Gallant, Research Physical Scientist, U.S. Geological Survey – Earth Resources Observation and Science Center

Introduction. Detailed landscape information is a necessary component to bird habitat conservation planning. The U.S. Geological Survey (USGS) Earth Resources Observation and Science (EROS) Center has been providing information on the Earth's surface for over 40 years via the continuous series of Landsat satellites. In addition to operating, processing, and disseminating satellite images, EROS is the home to nationwide and global landscape mapping, monitoring, and projection products, including:

- National Land Cover Database (NLCD) – the definitive land cover dataset for the U.S., with updates occurring at five-year intervals;
- Global Land Cover Monitoring – producing 30m resolution global land cover;
- LANDFIRE – Landscape Fire and Resource Management Planning Tools–EROS is a partner in this joint program between U.S. Department of Agriculture and Department of Interior that produces consistent, comprehensive, geospatial data and databases that describe vegetation, wildland fuel, and fire regimes across the U.S.;
- Land Cover Trends – a landscape monitoring and assessment effort to understand the rates, trends, causes, and consequences of contemporary U.S. land use and land cover change; and
- Land Use and Land Cover (LULC) Modeling – a project extending contemporary databases of landscape change forward and backward in time through moderate-resolution land cover projections.

These efforts produce the standard nationwide geospatial data upon which many habitat assessments and planning efforts begin. Local or regional spatial datasets can provide more thematically (e.g., more vegetation classes) and spatially (i.e., smaller pixel size) detailed information for specific regions, but often lack the broad, nationwide scope upon which to build cross-boundary habitat assessments. These issues of geospatial scope and scale were just a few of the topics brought up at the *Symposium to Advance the Integration of Remote Sensing Technology into Habitat Conservation Planning Tools* held in fall 2014 in Washington D.C. Scientists at EROS look forward to continuing to work with our many data users to conduct geospatial research and deliver data products useful to the bird habitat conservation community. The following segments highlight a few of the many advancements being made at EROS in the areas of LULC mapping, forecasting, and analysis.

Land Cover Monitoring, Assessment, and Projection. The remote sensing/land cover mapping community is undergoing a paradigm shift in how remote sensing data are processed, distributed, and used to create geospatial mapping products. Continuing advancements in computer processing power and software development are enabling the rapid processing of remote sensing data into analysis-ready products, such as Web-Enabled Landsat Data (WELD, see http://weld.cr.usgs.gov). EROS is undertaking a radical, new approach for using the Landsat satellite archive to identify changes in land cover type and condition. The traditional approach has been to compare changes in the landscape based on two periods in time. This can be problematic because ephemeral conditions, such as cloud shadows and haze, recent precipitation, and stage of seasonal development of vegetation, can alter the responses detected by the satellite sensor and "fool" a change-detection algorithm into incorrectly interpreting the land cover.

An approach EROS is currently testing uses all available Landsat observations at a pixel level to characterize each satellite image pixel's response history based on all clear observations in the archive (as far back as the early 1980s, with the potential one day to use the full Landsat period of record back to the early 1970s). This fuller understanding of a pixel's history provides a more robust foundation for identifying when its response signal deviates from longer-term patterns of behavior. The new technique, developed at Boston University by Drs. Z. Zhu and C. Woodcock, not only will enable EROS to detect abrupt changes in the landscape, but also to characterize response patterns of gradual forms of change, such as vegetation succession, post-disturbance recovery, and decline (see Figure 1). Moreover, the approach lends itself to being implemented in a continuous manner, providing an opportunity to detect change in near-real time.

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This ability to better pinpoint the timing of change and to provide frequent updates on the status of the landscape at a 30-meter spatial scale will be unprecedented and will allow us to improve our understanding of the linkages between drivers and outcomes of change. We also can start exploring combinations of land cover types and landscape conditions in ways difficult to analyze in the past. One example of this is mapping the distribution of early successional vegetation for bird species having that habitat requirement.

By taking better advantage of the depth of information available in the Landsat archive, we ultimately can create better land cover maps, expand the ways in which information on land cover can be used to support studies on potential effects on birds, and provide improved foundational data for building scenarios and projections of landscape change.

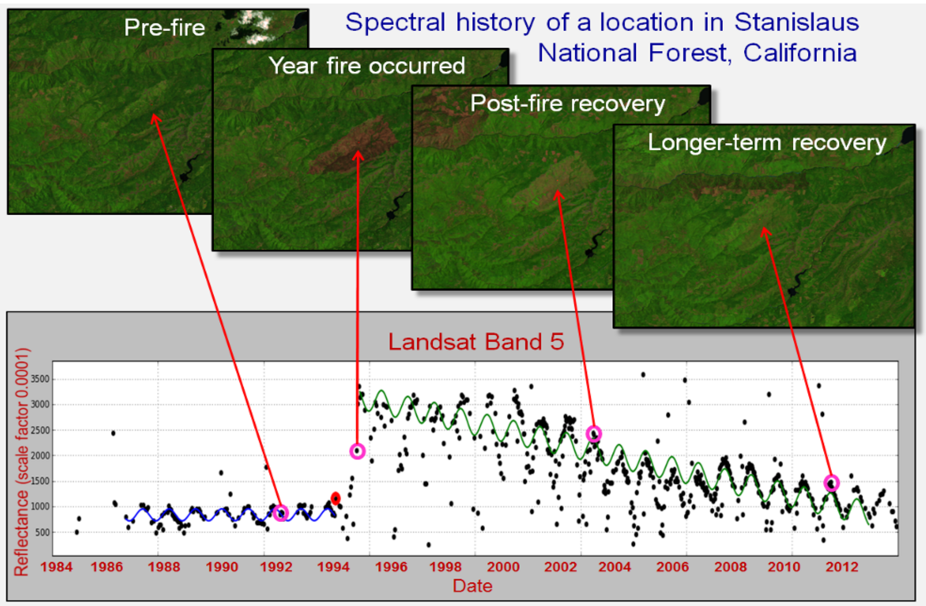

Figure 1. This graph from a continuous change-detection algorithm illustrates a pixel's energy signal over time. An abrupt break in the signal during the mid-1990s was caused by a forest fire, which removed all the vegetation and caused a brighter response from that location on the ground. Vegetation recovery in the years following the fire gradually reduced the brightness of the land as the pixel slowly settled into more predictable behavior. The wavy lines in the graph indicate annual phenological cycles of the pixel's response and highlight the difference between the cycles of a mature forest (blue line) and a recovering forest (green line). / Alisa Gallant

Land Use/Land Cover Modeling. Understanding potential changes in climate and LULC is vital for bird habitat conservation planning. LULC change can have dramatic effects on future landscape carrying capacity and understanding potential future landscape change can help conservation planners set appropriate habitat objectives required to meet future population goals.

High quality (i.e., accurate and appropriate spatial and thematic resolution) landscape data are difficult to acquire for regional to national applications. Forecasted LULC data are even rarer, as there are few available options and even fewer tools for creating climate-sensitive LULC projections. The LULC Modeling group at EROS is working to help address these data issues with the continuing release of regional/national LULC projections, as well as giving users the tools to customize their own projections through the development of stand-alone publicly available LULC modeling tools.

Using EROS's homegrown LULC forecasting model, FORE-SCE (FOREcasting SCEnarios of Land Use Change), we have produced national-scale LULC projections from 1992-2100 consistent with future climate change scenarios as part of the USGS's LandCarbon project. A modified version of the 1992 NLCD was used as the starting land cover, with 16 thematic LULC classes and 250m pixel spatial resolution (Figure 2). The future scenarios were based on qualitative storylines associated with the Intergovernmental Panel on Climate Change (IPCC)-Special Report on Emission Scenarios (SRES). Four scenarios were modeled: A1b, A2, B1, and B2, representing a range of future socioeconomic and biophysical conditions. For more information on the IPCC-SRES scenarios and how they were used in this analysis, visit http://www.sciencedirect.com/science/article/pii/S0959378012000325.

Greater future increases in anthropogenic LULC generally were more likely to occur in the more economically-oriented "A" scenarios. The more environmentally-oriented "B" scenarios saw more moderate increases in agricultural/urban land uses with some restoration of natural cover types in certain regions. Examples in the differences across scenarios are evident in the Kansas City, Missouri-area (see Figure 2).

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Along with forecasting future LULC, we modeled annual changes from 1992-2100 in forest-stand age. Starting stand age for all forest pixels in the 1992 NLCD were created based on interpolating the U.S. Forest Service's Forest Inventory and Analysis program data points. Forest age matured annually until it changed land cover type or was clear-cut. The stand age layer was also used to ensure realistic cutting cycles by regionally adjusting the size of areas harvested for timber and frequency of repeat cutting. The combination of thematic land cover and forest-stand age provides options to assess land cover impacts on biodiversity due to both land use and forest structure. In addition to future land cover projections, we have also created historical simulations of LULC change using

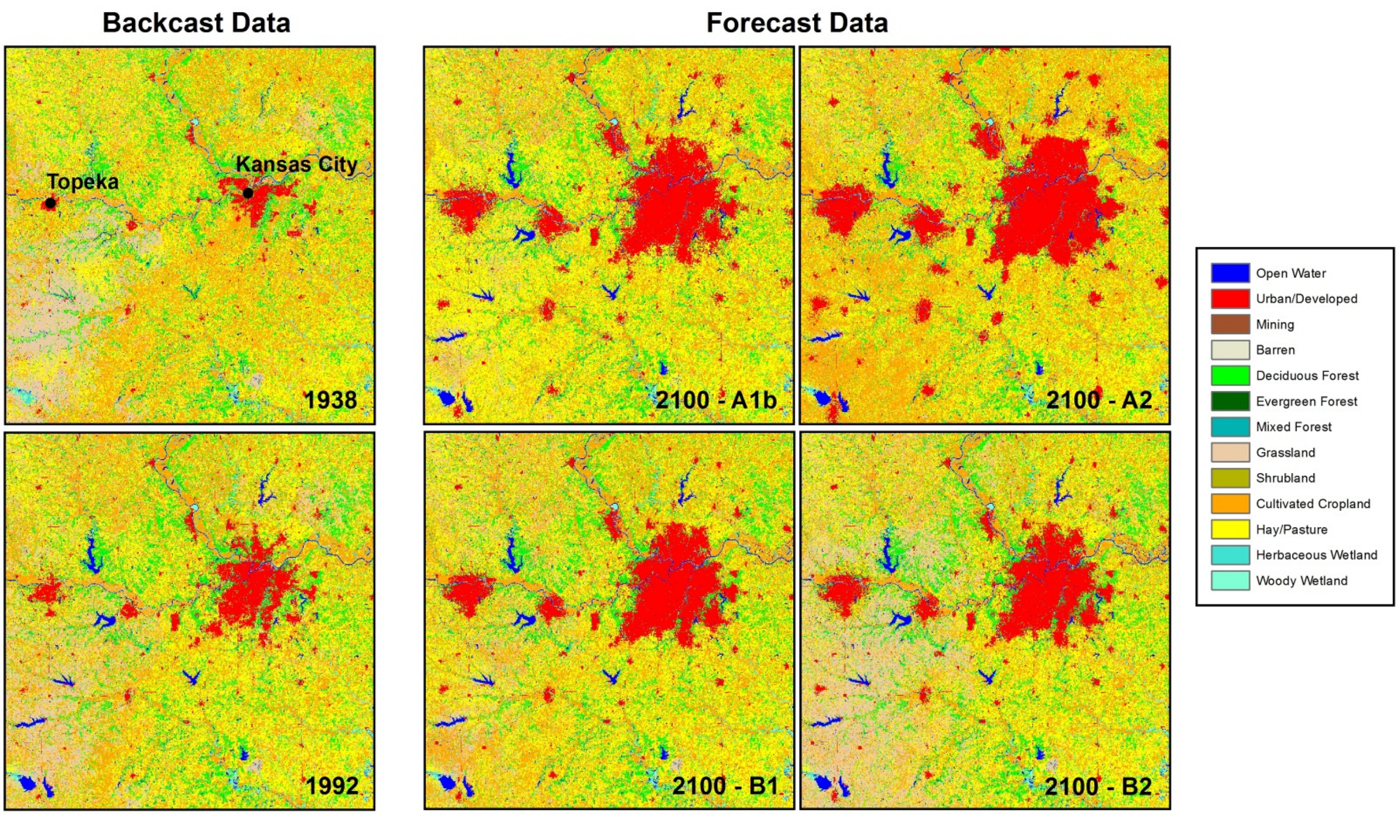

Figure 2. Example of historical and future LULC projections for the Kansas City, Missouri-area. 1938 shows lower amounts of cultivated cropland and smaller cities, and pre-dates the area reservoirs. Urban areas increase in all future scenarios but are more clearly pronounced in the high-growth A scenarios. Both A1b and A2 scenarios show decreases in natural land cover due to increases in urban area and conversion to agricultural cover types. Even in the more environmentally oriented B2 scenario, agricultural conversions to more natural cover types are relatively low. / Ryan Reker

FORE-SCE. Based on the same thematic and spatial characteristics as the LandCarbon projections, we modeled historical LULC change from 1992 back to 1938. The historical simulations were based on county-level U.S. Census of Agriculture statistics, Population Census data, the USGS Protected Area Database, and a variety of other historical information. The conterminous U.S. historical modeled data, when coupled with the LandCarbon forecasts, provide a greater than 160-year dataset of consistent annual modeled land cover.

While these unique projections offer researchers from many fields the opportunity to examine future and historical impacts of LULC change on ecological processes, the selected drivers and spatial and thematic characteristics may not be ideal for all applications such as habitat modeling efforts requiring more thematically specific vegetation conditions. Recognizing this, we want to shift the focus from solely being providers of projected LULC data, to also being providers of tools enabling conservation scientists to produce customized, climate-sensitive, LULC projections tailored to meet their individual needs.

To this end, we are creating a version of FORE-SCE available to the public and offering flexibility in spatial, thematic, and temporal parameters. Providing the tools to allow stakeholders to create their own LULC projections should increase the availability and the use of forecasted LULC data, improving the capability of conser-

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vationists, planners, and decision-makers to account for potential changes in climate and LULC. For more information on LULC modeling activities at USGS-EROS, to download data, or stay abreast of the upcoming public modeling framework, visit our website at http://landcover-modeling.cr.usgs.gov/.

Using projected LULC and climate data in species distribution modeling. In addition to creating forecasted land cover data, we are conducting analyses on how projected climate and land cover may influence future ecological processes. Bird habitat and species distributions have been shown to be influenced by changes in climate and LULC. We used a species distribution model to examine the relative future impacts of climate and LULC change on bird distributions. Species distribution models (SDMs) use data on environmental conditions (e.g., climate, land use, topography) to determine a local site's ability to support the reproductive, foraging, and sheltering needs of a species. Projected climate data are often used in SDMs to examine changes in species response or shifts in distribution due to climate change. LULC data are often used as proxies for habitat in SDMs for current or historical periods, but have rarely been used to model the impacts of future LULC change.

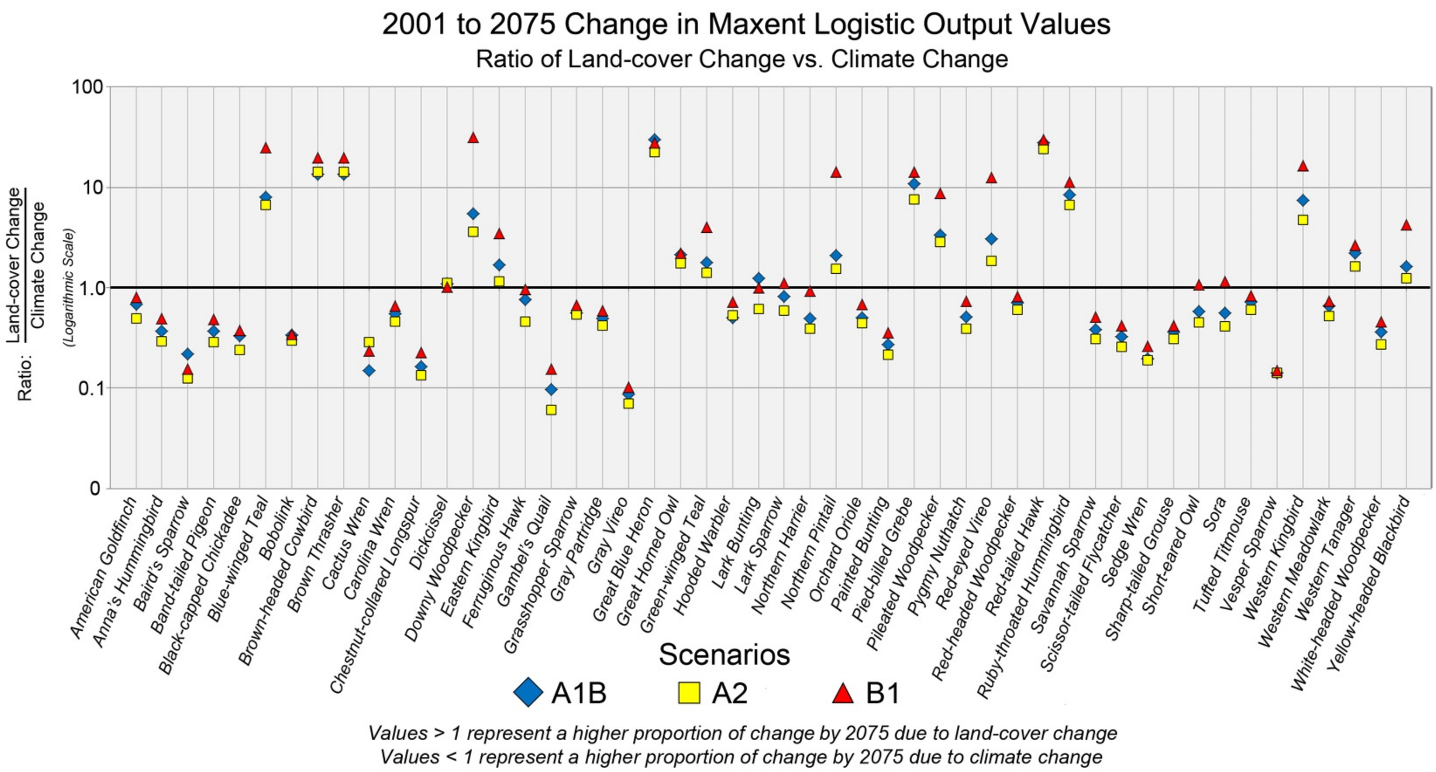

Figure 3. A ratio technique was used to measure the relative influence of land cover vs. climate change on modeled species suitability scores. Species with values > 1.0 were more strongly influenced by land cover change, and species with values < 1.0 were more strongly influenced by climate change. Although two-thirds of species were more strongly influenced by climate, there were a number of species with stronger responses to land cover change. / Terry Sohl

Using the LandCarbon LULC projections and climate data consistent with the associated Intergovernmental Panel on Climate Change Special Report –Emissions Scenarios, we conducted a study to assess the relative impacts of climate and land use change on conterminous U.S. bird populations from 2001 to 2075. Species occurrence data for 50 different species were obtained from eBird, a citizen-science database of bird sightings. A maximum-entropy model (MaxEnt) was used to model contemporary (2001) bird distributions using both climate and LULC data, and with either LULC or climate data excluded. The model developed for 2001 was applied to 2075 by substituting the projected LULC data, the projected climate data, or both. By withholding climate or LULC in turn for both 2001 and 2075, the individual impacts of climate and LULC on both contemporary and future bird species distributions was assessed.

Model "fit" for 2001 bird distributions was significantly poorer if either LULC or climate data were excluded from the model, with lowest model fit overall if LULC data were excluded. The estimated statistical

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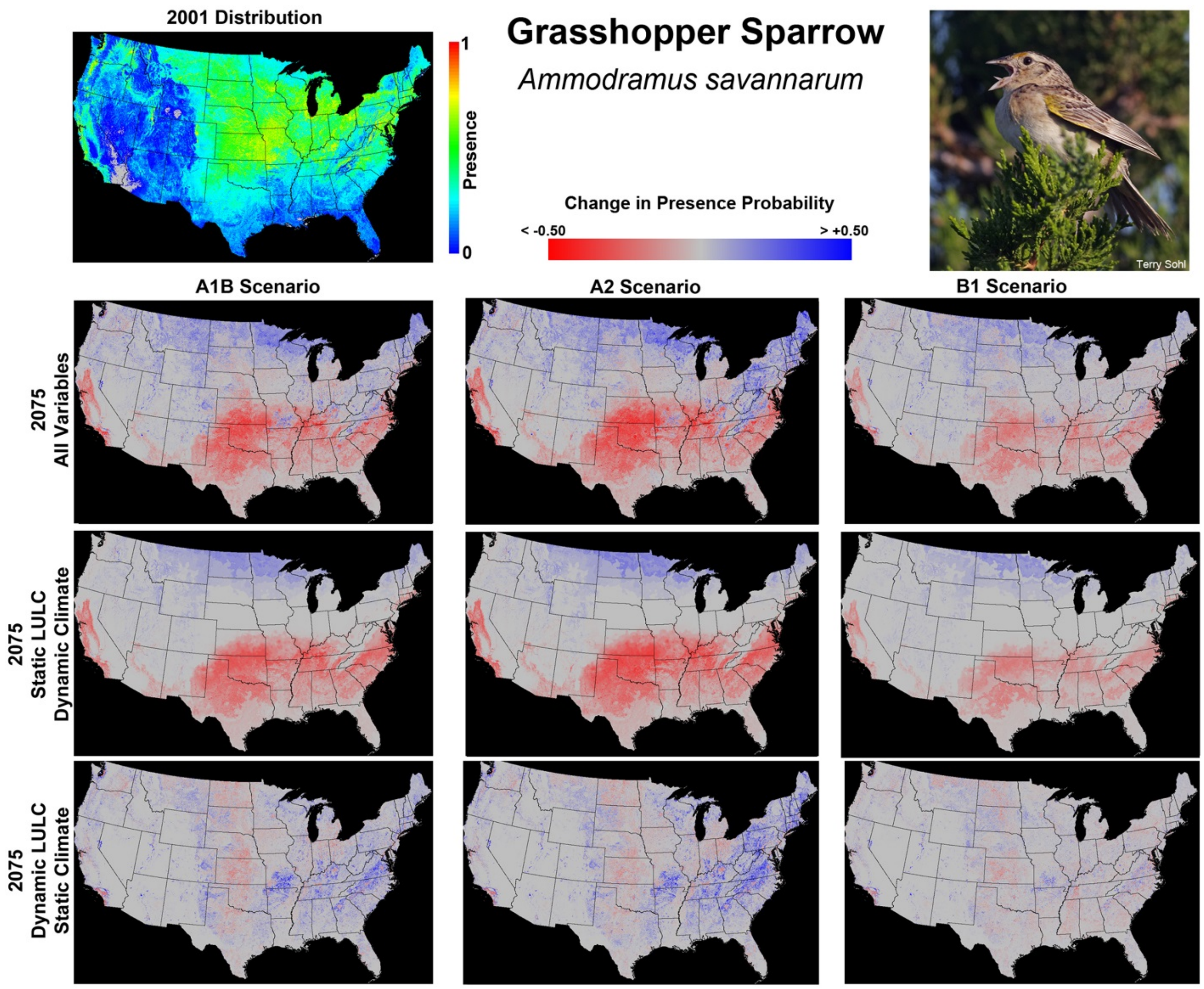

Figure 4. Modeled range for Grasshopper Sparrow. The upper-left map represents current range, and the maps below represent changes in suitability for the species, dependent upon scenario, and whether climate, land cover, or both were dynamic in the future. Climate change resulted in a broad band of lower suitability scores in the south. The clearing of forest in the eastern U.S. resulted in an increase in suitability in many areas. / Terry Sohl

contribution of the climate and LULC covariates to distribution model results was similar, with climate contributing slightly more than LULC data. The area deemed to be "suitable" to support a given species often varied dramatically dependent upon which variables were used as covariates. The area deemed suitable was nearly double in some cases (e.g., Great Horned Owl, Yellow-headed Blackbird) if LULC data were excluded from the analysis. These and other results suggest that climate alone may provide a broad-brush map of suitability, but LULC data are necessary to more precisely define species range.

The change in species ranges by 2075 also varied in relation to which covariates were modeled. Change in range varied from a near complete loss of all conterminous U.S. suitable range (e.g., for Baird's Sparrow) to range expansions that nearly double the current U.S. range (e.g., Cactus Wren, Gray Vireo). Overall, the magnitude of projected changes in range was more strongly impacted solely by projected climate change than solely by projected LULC change. However, for approximately one-third of the modeled species, LULC change more strongly affected change in species "presence" scores than did climate (see Figure 3).

Results from this study may contradict the findings of the few other studies that have modeled the impacts of both projected climate and LULC data, but all previous studies were conducted using data with coarse spatial resolutions (20-km, 50-km, or 0.5-degree grid cells) that may not adequately capture more local-scale LULC dynamics.

Continued Page 27

Using Satellite Remote Sensing to Map Changes in Wetland Plant Cover in the Sacramento-San Joaquin River Delta of California

Christopher Potter, Senior Research Scientist, National Aeronautics and Space Administration–Ames Research Center

Figure 1. The Sacramento-San Joaquin River Delta (box outline) in the San Francisco Bay Area of California. / State of California

The Sacramento-San Joaquin River Delta (hereafter referred to simply as "the Delta") can be viewed as an extensive agricultural landscape surrounded by urbanization, tidal freshwater wetlands, and major commercial waterways originating from California's two primary river systems—Sacramento and the San Joaquin—that flow into San Francisco Bay (see Figure 1). Much of the Delta's land cover is partitioned into discrete island tracts separated from open waters by human-made levees. Through decades of soil erosion, peat decomposition, and subsidence, many cropland tracts have fallen far (10 meters) below sea level, and active maintenance of the levee system is required to protect Delta farmlands from flooding.

Bird habitats of the Delta have been among the most modified by human activity in the United States. The Delta was once a great tidal marshland of peaty alluvial soils. Pre-settlement vegetation consisted largely of native "tule" (bulrush) and reed marshes that were periodically submerged, with narrow patches of riparian forest on the natural levees along the major stream channels. In the late 1800s, new and higher levees were built along the stream channels to protect the land from flooding, and the resulting complex of Delta island tracts were extensively drained, cleared, and planted to croplands.

Today the Delta may be the world's most extensively invaded estuary by exotic plant species. Water Hyacinth is one of the primary invasive weed problems in Delta waterways because of its prolific floating biomass that interferes with pumping equipment for agricultural water supply and recreational activities such as boating and fishing. Excessive Water Hyacinth biomass may alter water quality and provide habitat for undesirable disease-carrying insect species.

Researchers at NASA's Ames Research Center, located about 40 miles southwest of the Delta, are using satellite imagery from the Landsat sensor to regularly detect the location and abundance of Water Hyacinth (and potentially other emergent aquatic plant species) in all Delta waterways and in bird habitats throughout the San Francisco Bay Area (SFBA). The archive of Landsat images extends back to the early 1980s, making long-term change studies of wetland habitats uniquely feasible.

The mapping method starts from the selection of near cloud-free imagery from the U.S. Geological Survey Earth Explorer data portal (http://earthexplorer.usgs.gov/). An early September anniversary date window is targeted each year to minimize variation caused by seasonal vegetation growth and sun angle differences. The linear relationship between fresh (live) green biomass (LGB) of emergent aquatic vegetation in the SFBA and two Landsat bands was adopted from the study by Zhang et al. (1997; Ecological Applications, 7(3), 1039–1053; http://www.esajournals.org/doi/abs/10.1890/1051-0761%281997%29007%5B1039%3AMPCSMU%5D2.0.CO%3B2?journalCode=ecap). The equation for prediction of LGB was based on conversion of the simple ratio between the reflectance in the red band (centered at 0.655 micrometers) and the near-infrared (NIR) band (centered at 0.865 micrometers).

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Over 30 locations were visited by boat on October 1, 2014, to verify the presence and visually estimate the percent (water area) cover of Water Hyacinth dominated habitat in Delta waterways. Geo-coordinate locations and digital photographs were recorded for floating patches of Water Hyacinth that were nearly 30x30 meters in water coverage area. Several control locations dominated by tule reeds (and no apparent Water Hyacinth) were also recorded. The percent area coverage of Water Hyacinth plotted against estimated LGB of emergent aquatic vegetation from September 2014 Landsat imagery showed a 80 percent overall accuracy. Nearly all locations observed first-hand in October 2014, that were estimated to have greater than 50 percent Water Hyacinth cover, also were estimated by Landsat to have greater than 3,000 grams LGB per square meter. It was projected from the satellite imagery that a total of 3,180 acres of Delta waterways were covered by greater than 50 percent Water Hyacinth in late 2014.

Delta waterways (foreground) and native wetlands (background) infested by Water Hyacinth, surrounding abandoned farming equipment in 2014. / Chris Potter

For a closer examination of changes in wetland biomass cover over the past 25 years, The Nature Conservancy's bird-friendly Staten Island provides an outstanding case study. The Nature Conservancy bought the 9200-acre island tract in 2001, mainly to safeguard Delta habitat for migratory birds. Fifteen percent of all Greater Sandhill Crane—a California threatened sub-species—that fly into the Central Valley each year along the Pacific Flyway use Staten Island as wintering habitat. The flyway is a crucial migratory pathway for more than five million birds, and Staten Island is the winter home for hundreds of swans, geese, ducks, herons, and shorebirds such as plovers and sandpipers.

Staten Island is presently managed to be wildlife-friendly. After the corn that is grown on a large portion of the island is harvested in September, the stubble is mulched to provide optimal foraging for cranes, which feed on the leftover grain. The island is then flooded with fresh river water by pumps to promote the growth of invertebrates as bird food and to create crane roosting sites and habitat for other birds such as waterfowl, shorebirds. Cranes roosting in the shallow water gain some protection from predators (e.g., coyotes).

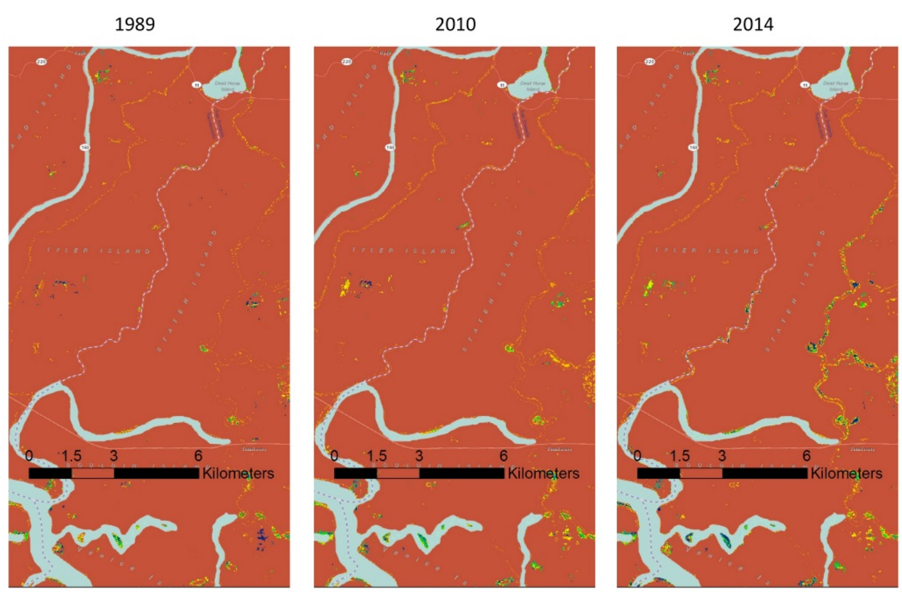

Figure 2. Landsat image products from 1989 to 2014 for the Delta area around Staten Island. Color legend: Brown – Cropland, Yellow/Green – Low biomass wetlands, Dark Blue – High biomass wetlands, Light Blue – Open waterways. / Chris Potter

A time series of Landsat images starting in 1989, was used to map changes in wetland LGB around Staten Island (see Figure 2). This 25-year record of change shows a proliferation of high biomass cover associated with invasive aquatic weeds after 2010, in the river courses mainly to the east and south of Staten Island. Infestation by Water Hyacinth in these wetlands can crowd out native plants and make transfers of river water for irrigation onto Delta Islands more difficult and expensive.

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Landsat imagery has several advantages over other (aircraft-mounted) sensors used periodically to detect aquatic wetlands plants. Landsat images are acquired by NASA every two weeks throughout the year everywhere in the United States, and are free of charge for download. Monthly mapping of wetland plant biomass by Landsat can be undertaken for all bird habitats and flyways in the nation, including the reconstruction of several recent years of region-area coverage before and after treatment for weed removal by local officials.

Full map coverages for the Legal Delta of emergent aquatic plant biomass are being posted and updated regularly for download on the internet viewer, which is publicly accessible at http://cquest.arc.nasa.gov:8399/flexviewers/sf_wetlands/.

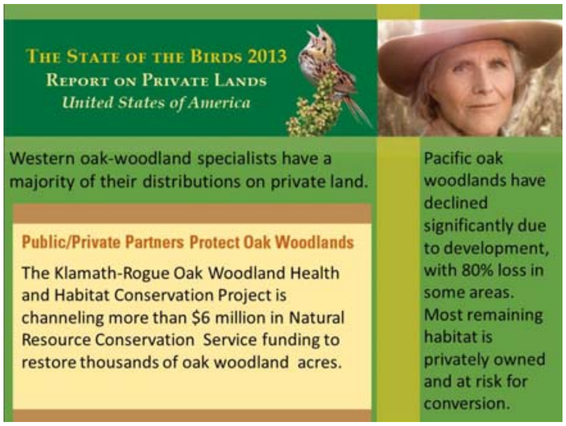
For more information, contact Chris Potter at chris.potter@nasa.gov.

Acknowledgements. The author is grateful for the boat transportation assistance in the Delta from the State of California's Department of Parks and Recreation, Division of Boating and Waterways, Aquatic Invasive Species Program. Thanks to Laura Shaskey, Staten Island Conservation Program Manager for Conservation Farms and Ranches and The Nature Conservancy, for comments on an earlier version of this article.

Above: Newly cropped field on Staten Island in April. / Chris Potter
Below: During the post-harvest winter season with Sandhill Cranes. / The Nature Conservancy

Using Birds to Predict Habitat Conditions: Species-centered Modeling Offers Novel Solutions to Conservation Challenges

John Alexander, Executive Director, Klamath Bird Observatory, Matthew Betts, Associate Professor, Oregon State University, Kate Halstead, Research Biologist, Klamath Bird Observatory, and Jaime Stephens, Science Director, Klamath Bird Observatory



The State of the Birds 2014 Report recognized the Klamath Siskiyou Oak Network of southern Oregon and northern California as an exemplary public-private bird conservation partnership. The Klamath-Rogue Oak Woodland Health and Habitat Conservation Project, highlighted in *The State of the Birds 2013 Report on Public Lands*, is just one of this network's projects that is guided by bird conservation priorities. Species-centered habitat distribution models are informing the conservation design to maximize the effectiveness of local restoration through a landscape implementation approach. / U.S. NABCI Committee

The 2013 and 2014 *State of the Birds* reports list birds associated with oak woodlands among the West's most at-risk forest species. These reports also highlight the Klamath-Siskiyou Oak Network partners and their exemplary science-driven projects, which are guided by oak woodland bird conservation priorities (http://www.klamathbird.org/the-klamath-call-note/news/1999). The Oak Network's restoration projects are maximizing the effectiveness of local restoration by taking a landscape approach to implementation in southern Oregon and northern California.

However, restoration planning efforts like this one are often limited by a lack of fine-resolution information regarding the distribution and condition of specific habitats such as oak woodlands. This information gap also limits the conservation community's ability to address broader issues associated with changing landscape conditions.

Fortunately, an alternative and cost-effective approach to modeling bird distributions and the application of resulting models to predict habitat availability has emerged from a collaboration between Klamath Bird Observatory (http://www.klamathbird.org/) and Oregon State University's Department of Forest Ecosystems and Society (http://fes.forestry.oregonstate.edu/). Large bird monitoring datasets made available from the Avian Knowledge Northwest node (http://www.avianknowledgenorthwest.net/) of the Avian Knowledge Network (http://www.avianknowledge.net/) are fuelling these novel modeling efforts. In turn, results are helping conservation partners overcome challenges associated with conservation design where fine-resolution land cover data are limited.

Unclassified remote sensing imagery data from Landsat Thematic Mapper (TM) satellites (http://earthexplorer.usgs.gov/) are used to produce species distribution models with high predictive success. The raw satellite data produce more accurate distribution models than models that use classified land cover data such as GAP vegetation maps. Classified data can be limiting because they are coarsely scaled and provide little or no information about habitat condition. Raw Landsat data, which are made freely available every year, allow for species distribution models that offer high-resolution predictions and avoid uncertainties relating to habitat misclassification, omission of fine-scale habitat features, and subtle changes in vegetation. The bird species distribution models are then used to predict subtle on-the-ground habitat characteristics at local and landscape scales.

The first step of this process (see Figure 1 A and B) is outlined in a paper titled *Species Distribution Modelling for the People: Unclassified Landsat TM Imagery Predicts Bird Occurrence at Fine Resolutions* (http://onlinelibrary.wiley.com/doi/10.1111/ddi.12093/abstract?deniedAccessCustomisedMessage=&userIsAuthenticated=false). This paper demonstrates how six bands of visible and infrared spectrums captured by Landsat TM can be used to produce distribution models that successfully predict occurrence for 40 bird species commonly occurring in western Oregon. The models account for the influence of subtle vegetation characteristics that are represented by the six bands of reflectance data (e.g., differences in vegetation structure and composition). Although such habitat characteristics or conditions are important drivers of bird distribution, they are rarely accounted for in species distribution models that depend on classified land cover data.

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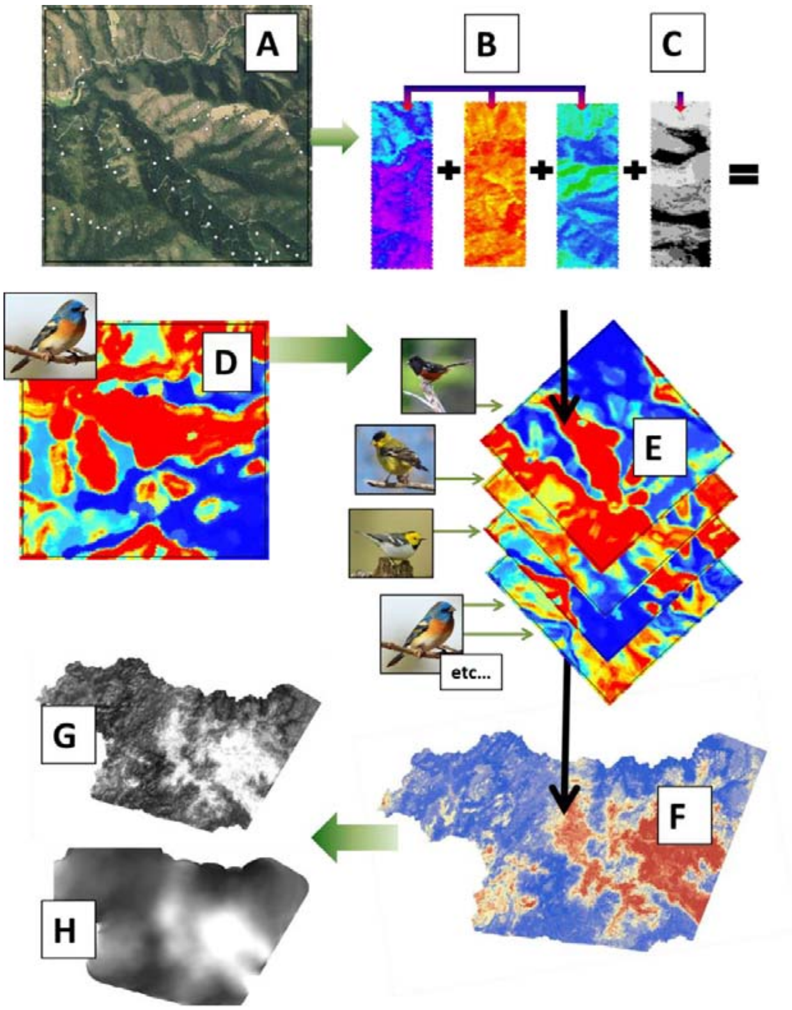

Figure 1. Conceptual figure for creation of local and landscape 'habitat amount' metrics for forest bird species of the Rogue Basin, Oregon. Process is as follows: A) Species occurrence data from an observational study is modeled as a function of predictors including B) Landsat TM land cover data and C) elevation. The resulting species distribution model (SDM) is used to interpolate probability of species occurrence across all pixels in a landscape; within this landscape subset (D), high probabilities of occurrence for Lazuli Bunting are red, and low probabilities are blue. Multiple SDMs for individual species are 'stacked', or summed (E), for a prediction of total richness at each pixel within a landscape (F). Finally, a moving window analysis is applied to calculate an index of habitat amount at a given scale, in this case, the mean of all pixels within a 150-m radius (G) and a 10,000-m radius (H) of each pixel in the landscape. For (G) and (H), highest summed mean values are white, and lowest values are black. (Originally published in *A 'Bird's Eye View': Using a Species-centered Approach to Examine Patterns and Drivers of Avian Species Richness in the Rogue Basin, Oregon, Oregon State University,*

The second step involves using these new bird distribution models to better understand habitat conditions across the landscape. The classified habitat data that limited species distribution modeling in the first place, also pose a challenge for habitat-specific conservation efforts such as the design of multi-scaled restoration projects. This is especially true in the heterogeneous oak woodlands of southern Oregon and northern California. Classified data often misclassify oak habitats and are too coarse to capture finer resolution features of habitat condition. These problems limit the use of classified data for developing effective landscape-scale restoration design as well as the design of site-specific restoration treatments.

To overcome these challenges, a graduate student employed the use of unclassified remote sensing imagery to predict bird distributions, which were then used to derive fine-resolution habitat models (see Figure 1 A through F). The study was titled *A 'Bird's Eye View': Using a Species-centered Approach to Examine Patterns and Drivers of Avian Species Richness in the Rogue Basin, Oregon* (http://ir.library.oregonstate.edu/xmlui/handle/1957/43265). In this thesis, distribution models derived for oak woodland associated species were stacked to predict the richness of species at local and landscape scales. Oak woodland species richness then served as a surrogate for oak habitat resulting in "species-centered" maps that predict the occurrence of oak habitats. These habitat maps were further tested in a paper titled *A Species-centered Approach for Uncovering Generalities in Organism Responses to Habitat Loss and Fragmentation* (http://onlinelibrary.wiley.com/doi/10.1111/ecog.00740/abstract?deniedAccessCustomisedMessage=&userIsAuthenticated=false). The additional tests demonstrated that the ability to predict species occurrence was more consistent when based on species-centered oak habitat maps than when derived from more typical classified oak habitat land cover data (see Figure 2).

With fine-resolution habitat maps in hand, the relative importance of landscape versus local habitat availability for oak associated and oak obligate species was then tested. Results were twofold. First, results demonstrated that landscape scale habitat availability is most important when considering a suite of 48 species that occur in oak habitats. This confirmed that configuring projects to maximize the amount of restored habitat at the landscape scale was an important consideration for the regional Klamath-Siskiyou Oak Network conservation effort. However, when considering 25 species that are oak obligates, the availability of oak habitat at the local scale was most important, suggesting that habitat condition at the restoration site is critical for these at-risk species.

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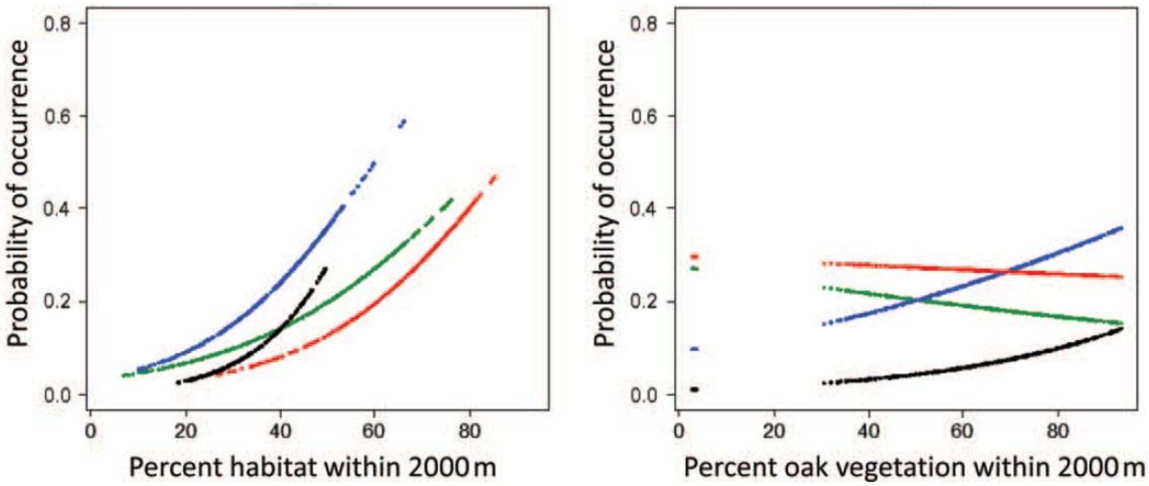

Figure 2. The probability of site occupancy varies strongly and consistently as a function of landscape structure quantified using a species-centered approach (left), but is highly inconsistent and weak when modeling it in response to classified vegetation type data (right). (Originally published in *A Species-centered Approach for Uncovering Generalities in Organism Responses to Habitat Loss and Fragmentation.* Ecography 37:517-527)
http://onlinelibrary.wiley.com/doi/10.1111/ecog.00740/abstract?deniedAccessCustomisedMes-sage=&userIsAuthenticated=false)

The novel modeling approach outlined here is relevant for both regional and local conservation planning, and for broader questions about conservation and changing conditions across large landscapes. The species-centered oak woodland habitat models provide a data-rich planning tool. These modeling products inform a conservation design process that balances important landscape and local habitat needs that, when considered together, ensure effective bird conservation at both scales. At the landscape scale, the species-centered maps offer fine resolution predictions of habitat availability that can be used to prioritize larger conservation areas, as well as local restoration sites, for maximum benefits to birds. Additionally, the habitat models offer species-specific information about at-risk oak obligate species that are likely to occur at sites. With this information, the habitat needs of these at-risk species guide restoration design. Recently published conservation plans, including a land manager's guide to oak ecosystems (http://www.klamathbird.org/images/kbo/pdfs_dsts/Altman_and_Stephens_2012_Land_managers_guide_to_oak%20ecosystem%20(Web).pdf) and a private landowner guide to oak restoration (http://www.klamathbird.org/images/kbo/pdfs_dsts/KBO_and_LRP_2014_Landowner_oak_guide_1.0%20(Web).pdf) offer details about habitat relationships and best management practices to ensure that restoration results in habitat conditions most likely to benefit bird species associated with oak woodlands.

Oak Titmouse is a *State of the Birds 2014* Watch List Species associated with oak woodland habitats. A Landsat derived distribution model for Oak Titmouse was used, along with distribution models for other oak woodland bird species, to create "species–centered" oak habitat maps./ Jim Livaudais

This species-centered modeling approach also offers a solution to challenges that limit our ability to assess landscape condition and changes at local, regional, and even continental scales. Unclassified remote sensing imagery can be used to produce species distribution models with high predictive success. Such models offer resolutions that allow us to understand landscape change at various spatial and temporal scales. With Landsat data at its core, and the increasing availability of spatially explicit bird occurrence and abundance data—through the Avian Knowledge Network and eBird—this species-centered modeling approach offers a valuable tool for harnessing information to predict subtle changes in landscape condition over time to address many different conservation challenges at various scales.

For more information, contact John Alexander at jda@klamathbird.org.

Integrating Remote Sensing Technology into Habitat Conservation Planning Tools: What Was Learned and Next Steps for Collaboration

Anne Bartuszevige, Conservation Science Director, Playa Lakes Joint Venture, Ed Laurent, Founder and Executive Director, Connecting Conservation, and Brad Potter, Science Coordinator, Upper Midwest and Great Lakes Landscape Conservation Cooperative

At the end of the day-long fall 2014 symposium in Washington, D.C., on integrating remote sensing technology into habitat conservation planning tools, significant energy emerged to build on existing and develop new collaborations between conservation scientists and remote sensing experts for the sake of better conservation outcomes. Attendees agreed that by working together we could tackle some of the difficulties of accurately depicting important areas for conservation, and tracking the conditions of the landscape through time that impact the birds and other species we care so much about.

For example, remote sensing scientists often have difficulty locating and accessing field verified vegetation data that can be used to "train" automated computer processes that classify remotely sensed (e.g., satellite and aerial photo) images into mapped vegetation classes. A greater number of field verified sites can increase the accuracy and precision of this vegetation classification process. Conservation biologists in attendance knew of several large vegetation datasets that could serve this purpose.

For example, vegetation data are often collected in the field alongside observations of birds. The Avian Knowledge Network (AKN; http://avianknowledge.net) manages and provides access to many bird observation datasets via several regional and thematic "nodes." Meeting participants agree to investigate the option of creating a botanical AKN node to archive and manage vegetation data for access by the remote sensing community. This option might involve developing a centralized repository or a set of networked repositories containing vegetation and bird abundance data as well as guidelines for how to collect vegetation data useful to remotely sensed vegetation classification processes.

Because many conservation scientists have geospatial data needs unique to their particular locale, they sometimes have difficulty locating appropriate data and analysis techniques. However, spatial analysts and remote sensing experts have solved many of these kinds of problems and so can offer solutions for similar situations instead of having conservation scientists work on their own to design new ones.

For example, user groups that are open to conservation biologists have been established for geospatial data like LANDFIRE, EROS and NASA. In these settings, users have the opportunity to share innovative data management and analysis techniques that can be used to address geospatial conservation needs. The remote sensing user groups are interested in meeting the needs of non-traditional users such as conservationists. Discussions in these settings can lead to new scientific research and ways to tackle conservation-related problems that are interesting to both conservationists and geospatial scientists.

Remote sensing experts and conservation scientists undertake a lot of overlapping and sophisticated work. By increasing communications and collaboration, our collective knowledge and resources can be leveraged to solve complex landscape conservation problems. Discussions have begun within and across the Joint Venture (JV) and Landscape Conservation Cooperative (LCC) communities on how to best structure this exchange of ideas and information. We hope that in the near future we can develop a framework to help address some of the common geospatial conservation problems like tracking landscape change. Stay tuned.

In the meantime, pick up the phone and start a conversation with a conservation scientist or remote sensing expert near you. You can locate some of these experts by joining the 'Advancing Uses of Remote Sensing in Habitat Conservation' users group on Griffin Groups (https://griffingroups.com/groups/profile/154096). In this group you can connect with other scientists, both conservationists and remote sensing experts, who share a common interest in using remote sensing products to inform conservation decisions. This group is also being used to archive notes from the fall 2014 symposium, results from a survey of JV and LCC science coordinators on geospatial data needs, and discussions about additional opportunities for follow-up.

The North American Bird Conservation Initiative (NABCI) is a coalition of organizations and partnerships dedicated to advancing integrated bird conservation in North America.

The vision of NABCI is to see populations and habitats of North America's birds protected, restored, and enhanced through coordinated efforts at international, national, regional, state, and local levels, guided by sound science and effective management.

The goal of NABCI is to deliver the full spectrum of bird conservation through regionally based, biologically driven, landscape-oriented partnerships.

The All-Bird Bulletin is the news and information-sharing publication of the U.S. NABCI Committee. http://www.nabci-us.org

For subscription or submission inquiries, contact the Editor, Roxanne Bogart, U.S. Fish and Wildlife Service, 413-253-8582 or Roxanne_Bogart@fws.gov. To download back issues, visit http://www.nabci-us.org/allbirdbulletin.htm.

The All-Bird Bulletin publishes information on infrastructure, planning, science, funding, and other advancements in the field of integrated bird conservation and management. For submissions, include author's name, organization, title, and contact information. Pictures are welcome but not necessary.

From LANDFIRE, Page 12

using silent point counts, playback surveys, and playback surveys that incorporated estimates of detection probability. Links to each of these articles can be found in the bibliography on The Nature Conservancy's Conservation Gateway.

Program Improvement. Both GAP and LANDFIRE rely on data and information from local staff and experts from around the country. We strongly encourage everyone to provide local data and feedback to the programs. You can find guidelines for contributing local data to LANDFIRE to support the mapping and updating process or submit feedback at landfire.gov. If you have feedback on GAP program products or have comments on the program, select Contact GAP at gapanalysis.usgs.gov.

Summary. As remote sensing technology advances, our ability to inform and improve wildlife and wildfire management will continue to increase. In the meantime, the LANDFIRE and GAP Programs have established an important partnership to advance critical core datasets by building a second generation high thematic resolution land cover and updating national species models based on 2016 Landsat OLI. These products will represent significant refinements in the thematic and temporal data that have become central to ongoing research and monitoring work that supports bird conservation across the nation.

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From Landsat, Page 17

These results provide strong evidence that inclusion of LULC data improves model fit and helps to better define species ranges than do models that rely solely on climate data. For projected future changes in range, model results may be misleading unless both climate and LULC change are assessed. All species model results are available at http://landcover-modeling.cr.usgs.gov/sdm.php, including maps depicting modeled current and future range for each of the 50 species (see Figure 4). A more comprehensive discussion of the assessment can be found in a recent Public Library of Science (PLOS) ONE article *The Relative Impacts of Climate and Land-Use Change on Conterminous United States Bird Species from 2001 to 2075* by Terry Sohl. http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0112251

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Yellow-headed Blackbird. / Dave Menke