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U.S. Geological Survey Energy and Wildlife Research Annual Report for 2018

Circular 1447, Version 1.1, October 2018

U.S. Department of the Interior
U.S. Geological Survey

Cover. Top: Oil production in sagebrush ecosystem (Bureau of Land Management), and male sage grouse (Matthew Lee, U.S. Geological Survey [USGS]). Middle: Offshore wind energy production (Wikimedia, Creative Commons 4.0), and male surf scoter with global positioning system transmitter (Jonathan Fiely, USGS). Bottom: Fish ladder at McNary Dam, Oregon and Washington (Bonneville Power Administration, Creative Commons 2.0), and juvenile chinook salmon (from video by Kyle Martens, USGS, and edited by Rachel Reagan, USGS).

U.S. Geological Survey Energy and Wildlife Research Annual Report for 2018

Edited by Mona Khalil

A view of the Trans-Alaska Pipeline, from the northern Brooks Range. Photograph by Dave Houseknecht, U.S. Geological Survey.

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U.S. Department of the Interior
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U.S. Department of the Interior
RYAN K. ZINKE, Secretary

U.S. Geological Survey
James F. Reilly II, Director

U.S. Geological Survey, Reston, Virginia
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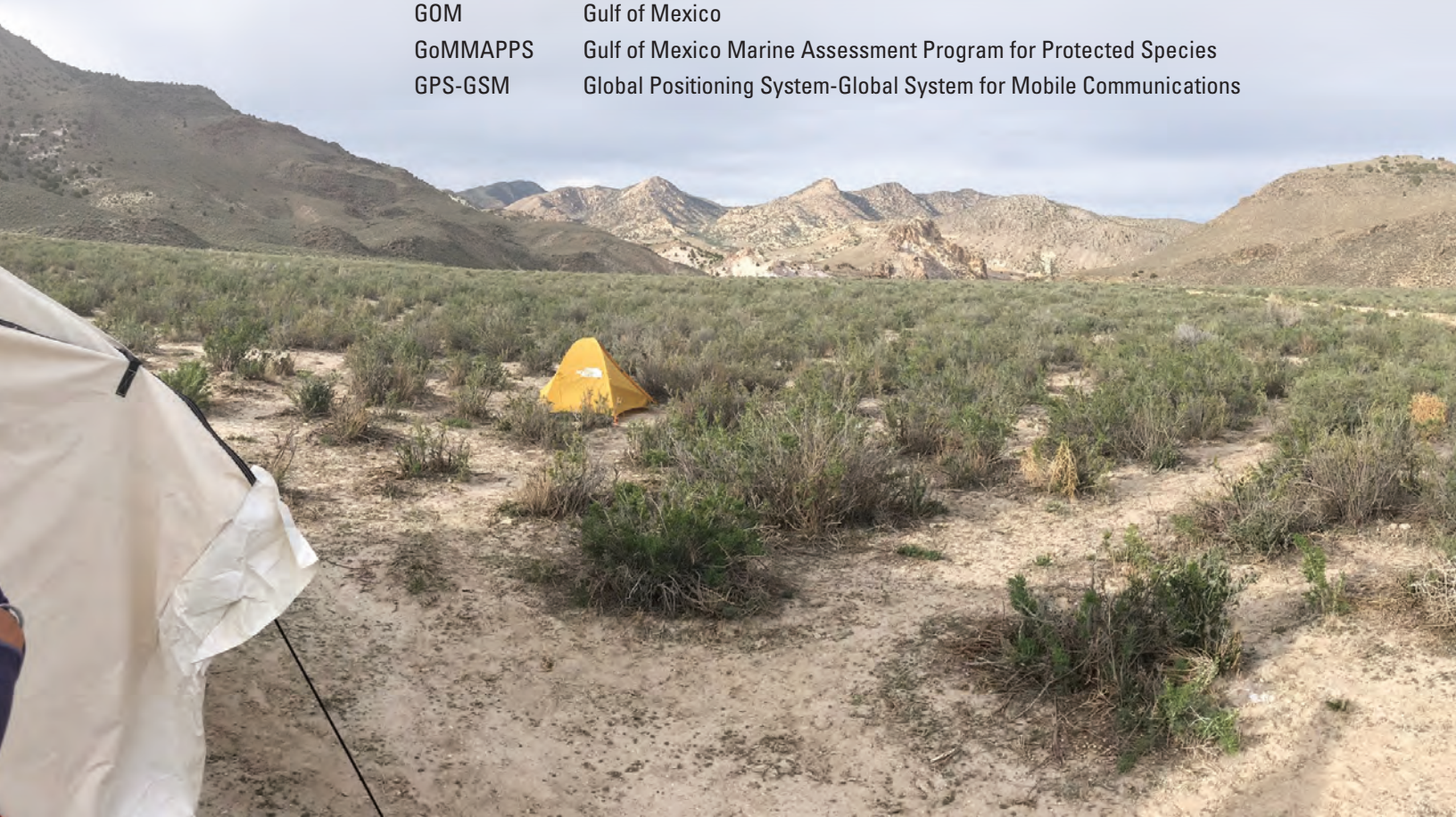
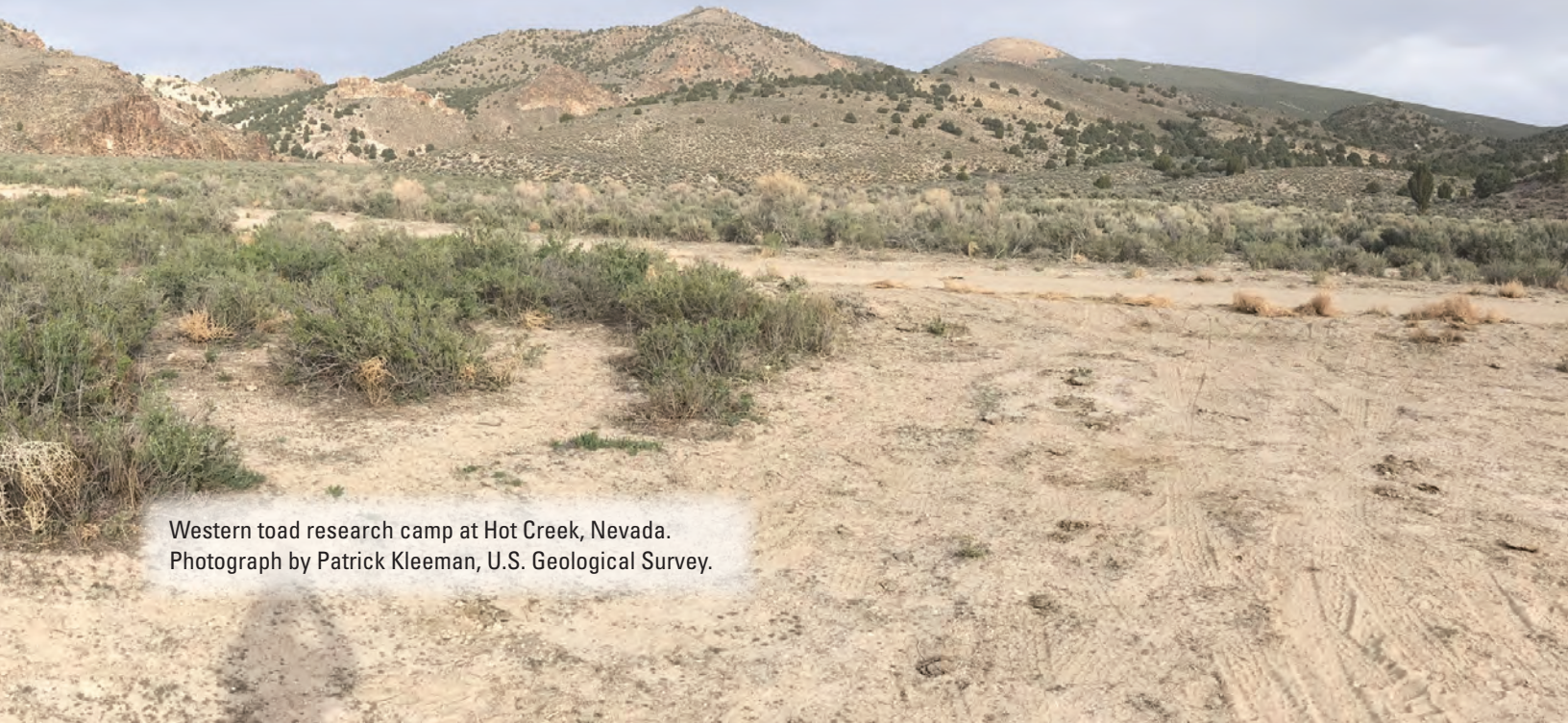
Contents

Abbreviations

AEA	Alaska Energy Authority
AWEA	American Wind Energy Association
BCI	Bat Conservation International
BLM	Bureau of Land Management
BOEM	Bureau of Ocean Energy Management
BOR	Bureau of Reclamation
BSEE	Bureau of Safety and Environmental Enforcement
CBM	coalbed methane
DEEP SEARCH	Deep-Sea Exploration to Advance Research on Coral/Canyon/Cold Seep Habitats
DISCOVRE	Diversity, Systematics and Connectivity of Vulnerable Reef Ecosystems
DNA	deoxyribonucleic acid
DOE	U.S. Department of Energy
DOI	U.S. Department of the Interior
DRECP	Desert Renewable Energy Conservation Plan
DWH	Deep Water Horizon
eDNA	Environmental DNA
EIA	U.S. Energy Information Administration
EPA	U.S. Environmental Protection Agency
FSC	floating surface collector
GIS	geographic information system
GOM	Gulf of Mexico
GoMMAPPS	Gulf of Mexico Marine Assessment Program for Protected Species
GPS-GSM	Global Positioning System-Global System for Mobile Communications



MFTB	Mexican free-tailed bat
MHI	main Hawaiian Islands
NABat	North American Bat Monitoring Program
NEXRAD	Next Generation Weather Radar
NGO	nongovernmental organization
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOPP	National Oceanographic Partnership Program
NPR–A	National Petroleum Reserve–Alaska
NPS	National Park Service
OCS	Outer Continental Shelf
OER	Office of Exploration and Research
PPR	Prairie Pothole Region
PVA	population viability analysis
SDM	structured decision making
UOG	unconventional oil and gas
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UV	ultraviolet
WEC	wave energy conversion
WLCI	Wyoming Landscape Conservation Initiative
WNS	white-nose syndrome



Western toad research camp at Hot Creek, Nevada.
Photograph by Patrick Kleeman, U.S. Geological Survey.

Wildlife technicians placing pygmy rabbit live traps.
Photograph by Stephen Germaine, U.S. Geological Survey.

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Science to Understand Risks, Measure Impacts, and Inform Solutions

Terrestrial and aquatic ecosystems provide valuable services to humans and are a source of clean water, raw materials, and productive soils. Healthy rivers contribute to commercial fisheries, native pollinators enhance agricultural crops, and insect-eating bats provide pest control services worth billions of dollars to farmers annually (Boyles and others, 2011). Fish and wildlife are vital to a vibrant outdoor recreation and tourism industry, which generates billions of dollars in revenue to States, large and small businesses, and local communities (Cullinane Thomas and others, 2018).

U.S. Geological Survey (USGS) scientists study and monitor fish and wildlife, providing natural resource managers evidence-based information on the status and trends of species of interest. A rigorous scientific process is applied to understand risks, measure impacts, and inform solutions to national and local challenges facing both humans and wildlife. Energy security remains a national priority, and the United States is expanding access to vast natural resources to produce electricity as well as petroleum and natural gas products to meet society's growing energy needs (U.S. EIA, 2017). Oil and gas production and wind and solar energy generation have shown consistent growth over the last 10 years. Currently, more than 57,000 wind turbines are contributing to power grids in 41 States, Guam, and Puerto Rico (American Wind Energy Association, 2018).

With expanding energy generation infrastructure across the Nation, some conflicts have surfaced. Effects of energy infrastructure include fragmentation and loss of habitat as well as mortality of birds, bats, fish, and other wildlife interacting with energy generation facilities. Because energy development often takes place in critical wildlife habitats, ecological science can be used to help guide project siting and operational decisions to areas and practices that present the lowest risk to energy development and wildlife. The USGS produces science that addresses challenges and develops workable solutions to help sustain wildlife and their habitats while allowing informed development.

Partners

USGS scientists work with more than 130 Federal, State, and local government agencies; Tribal nations; academic institutions; and nongovernmental (NGO) and private organizations to meet pressing science needs and deliver timely and relevant information related to energy development and wildlife.

USGS Mission

The USGS serves the Nation by providing reliable scientific information to describe and understand the Earth; minimize loss of life and property from natural disasters; manage water, biological, energy, and mineral resources; and enhance and protect our quality of life.

As the Nation's largest water, earth, and biological science and civilian mapping agency, the USGS collects, monitors, analyzes, and provides science about natural resource conditions, issues, and problems. Our diverse expertise enables us to carry out large-scale, multidisciplinary investigations and provide impartial scientific information to resource managers, planners, and other customers.

Energy and Wildlife Science Strategy

USGS scientists provide scientific information and options that land and resource managers and private industries can use to make decisions regarding the development of energy resources while protecting the health of ecosystems. Studies focus on delivering information to avoid, minimize, or mitigate the impacts of energy infrastructure on fish and wildlife. Research goals range from identification of a specific local issue to development of tools or techniques to address nationwide concerns.

USGS scientists are currently developing habitat-occupancy models for species of interest that can be overlaid with maps showing areas of potential energy. These models, or map overlays, identify areas of biological strengths and weaknesses or high- and low-quality habitat and can identify opportunities for conservation—areas of high-quality habitat where energy-generating potential is low—and areas of potential risk—areas of high-quality habitat where energy-generating potential is high. These tools can assist resource managers and the industry concerning siting of energy development and selection of off-site mitigation areas. Scientific efforts, such as these, further the understanding of impacts related to energy development and create workable solutions.

The three goals guiding USGS activities related to the interactions between wildlife and energy development are:

- Understand risks by identifying when, where, and how fish and wildlife share space with energy facilities
- Measure direct and indirect impacts to species
- Inform feasible and cost-effective solutions to minimize impacts through technological fixes, management, and mitigation

Updates to the Annual Report

This report features summaries of new and ongoing projects and publications on energy development impacts and solutions to address risks to wildlife. This year's report includes new sections featuring science on recovery and restoration following energy development; deep-sea research relevant to oil and gas development on the Outer Continental Shelf; and the use of environmental deoxyribonucleic acid (eDNA) in supporting management decisions. The section on science related to the effects of energy generation on fish and aquatic resources is reorganized by topic area, including fish passage and behavior near hydropower dams, and optimizing dam operations and management to address risks from invasive species, water quality, and flows. The section titled "Conservation and Energy Development Planning Tools" features science-based tools and approaches to assist resource managers in prioritizing areas for future energy development. The report also features sections focused on methods for fatality estimation and risk assessment in addition to broadly applicable management support tools.

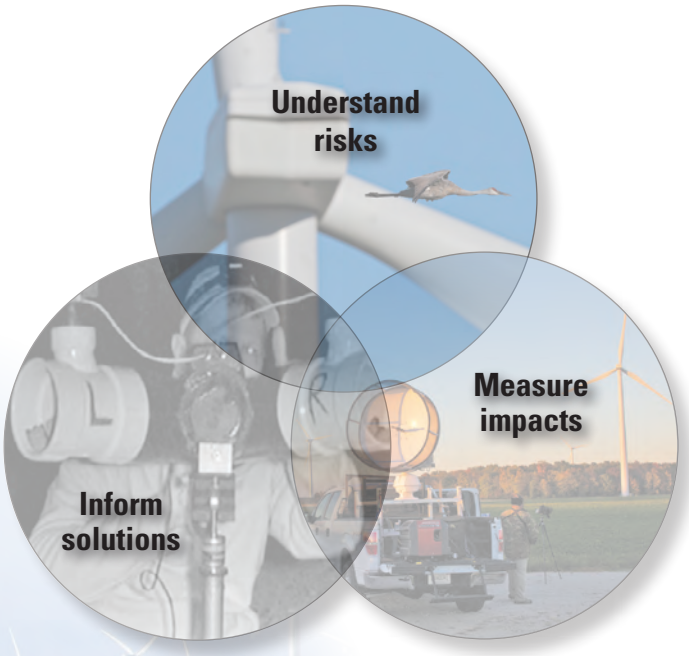


Figure 1. Three interrelated goals guiding USGS science in addressing energy development and wildlife.

List of Projects

Regulatory and management issues associated with energy development are often focused on the impacts on legally protected species and (or) other species and habitats of concern. USGS science efforts described in this report are organized by species or groups of species, habitats, and other topics considered most relevant to the U.S. Fish and Wildlife Service (USFWS), Bureau of Land Management (BLM), Bureau of Ocean Energy Management (BOEM), Bureau of Reclamation (BOR), and other Federal and State agencies responsible for permitting energy projects, conserving or managing species and habitats, and monitoring operations of renewable or conventional energy facilities.

Energy Icons

Each project is associated with a type of energy production or transmission. Types of energy production or transmission are represented by the following icons:


Biofuels


Oil and gas extraction


Electric generation


Solar energy


Electric transmission lines


Wave/tidal energy


Geothermal energy


Wind energy


Hydropower


Offshore wind energy


Mining/coal production

Icons modified from BSGStudio, all-free-download.com. Geothermal energy icon modified from VisualPharm, http://www.visualpharm.com/free_icons.html.

This oil rig in Wyoming is an example of long directional drilling, which can limit the amount of surface disturbance due to the rig's long reach. Photograph by Bureau of Land Management.

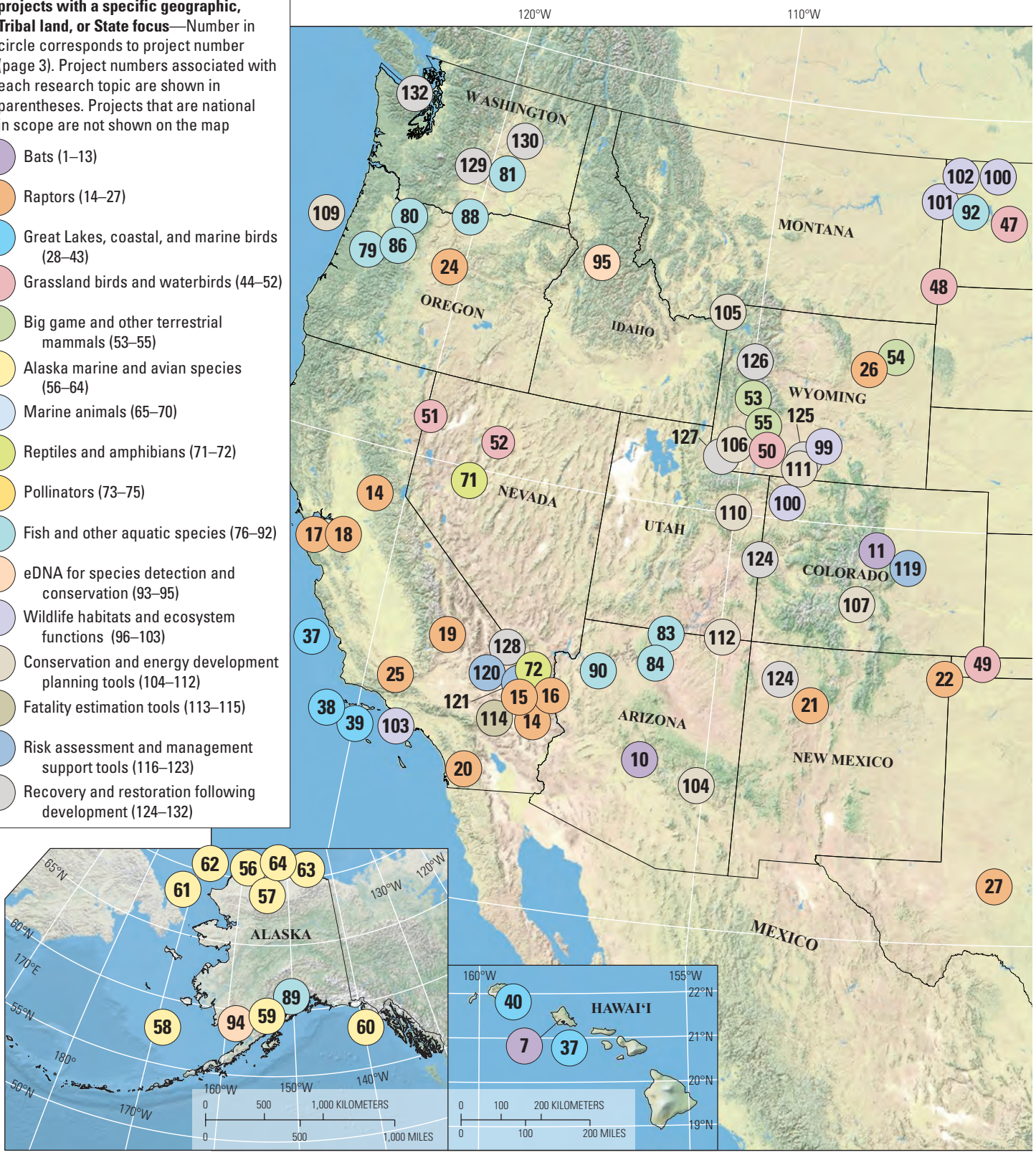
Study Locations

Click on the project number to access the project description.

EXPLANATION

U.S. Geological Survey Energy and Wildlife projects with a specific geographic, Tribal land, or State focus—Number in circle corresponds to project number (page 3). Project numbers associated with each research topic are shown in parentheses. Projects that are national in scope are not shown on the map

- Bats (1–13)
- Raptors (14–27)
- Great Lakes, coastal, and marine birds (28–43)
- Grassland birds and waterbirds (44–52)
- Big game and other terrestrial mammals (53–55)
- Alaska marine and avian species (56–64)
- Marine animals (65–70)
- Reptiles and amphibians (71–72)
- Pollinators (73–75)
- Fish and other aquatic species (76–92)
- eDNA for species detection and conservation (93–95)
- Wildlife habitats and ecosystem functions (96–103)
- Conservation and energy development planning tools (104–112)
- Fatality estimation tools (113–115)
- Risk assessment and management support tools (116–123)
- Recovery and restoration following development (124–132)

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PENNSYLVANIA
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DC
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IOWA
NEBRASKA
ILLINOIS
INDIANA
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WEST VIRGINIA
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MISSOURI
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TENNESSEE
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Wind turbines and rainbow in Hawai‘i. Photograph by Paul Cryan, U.S. Geological Survey.

Project Descriptions

Photograph by Paul Cryan, U.S. Geological Survey.

Bat colony flying at dusk.

Bats

Bat Migration and Distribution

1. The North American Bat Monitoring Program (NABat)

The USGS is the lead agency of a multiorganizational program called NABat, or the North American Bat Monitoring Program (NABat) (https://nabatmonitoring.org/). NABat members work to better understand the ecological consequences of population decline and risks from continuing and emerging threats, such as white-nose syndrome and wind energy, on 46 species of bats common to Canada, the United States, and Mexico. NABat's mission is to help resource managers and industry partners map bat distributions, better estimate extinction risk, and evaluate the effectiveness of conservation actions. The USGS has developed online data management and collaboration tools for bat monitoring, including services for archiving pre-construction acoustic recordings collected at wind energy facilities. Presently, NABat monitoring data have been collected in 39 States and 10 Canadian Provinces. NABat participants include State and Federal agencies, universities and NGOs, as well as private industry (for example, Duke Energy). Newly developed resources include a protocol for processing acoustic data collected to monitor the impacts of energy development on bats and advanced statistical modeling procedures to interpret acoustic monitoring data for bat population status and trends.

Contacts

Brian Reichert, USGS Fort Collins Science Center, breichert@usgs.gov, (970) 226–9245
Patricia Stevens, USGS Fort Collins Science Center, stevensp@usgs.gov, (970) 226–9499
Kathryn Irvine, USGS Northern Rocky Mountain Science Center, kirvine@usgs.gov, (406) 994–7492

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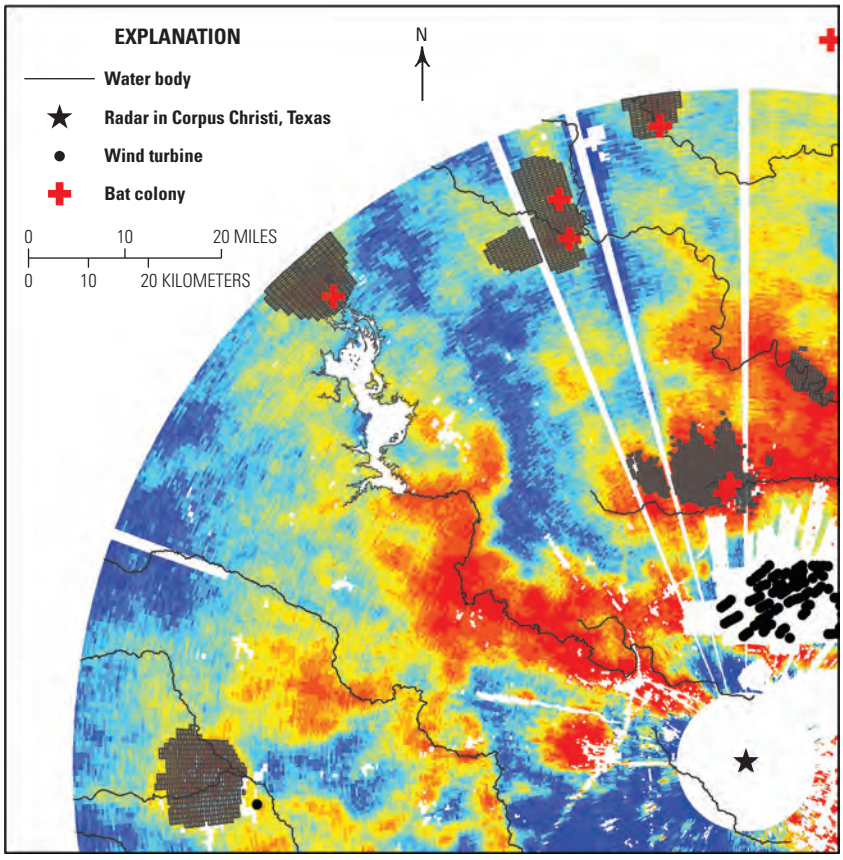
Rodhouse, T.J., Ormsbee, P.C., Irvine, K.M., Vierling, L.A., Szewczak, J.M., and Vierling, K.T., 2015, Establishing conservation baselines with dynamic distribution models for bat populations facing imminent decline: Diversity and Distributions, v. 21, no. 12, p.1401–1413, https://doi.org/10.1111/ddi.12372.

2. Using Weather Radar to Detect Bat Colonies in South Texas

USGS scientists, using weather surveillance radar data to quantify the stopover distribution of birds migrating through the Gulf of Mexico (GOM) region, detected partial ring signatures characteristic of bat movements. The scientists determined these signatures represented bats emerging from roost sites located under bridges within 80 kilometers of the Corpus Christi, Texas, radar station. Ground surveys of 8 of the 11 identified possible roost sites determined that 7 of those sites were occupied by Mexican free-tailed bats and other bat species. This study shows the utility of weather surveillance radar for locating bat colonies and monitoring regionwide bat movements.

Contact

Wylie C. Barrow, Jr., USGS Wetland and Aquatic Research Center,
barroww@usgs.gov, (337) 266–8668



Weather radar data can be used to study bird distributions and to locate bat colonies and monitor regionwide bat movements. In this image, bird activity is denoted by yellow to red hues. Gray indicates areas dominated by bat activity.

3. Pre- and Post-Hibernation and Migratory Activity of Bats in the Central Appalachians

The USGS and Virginia Polytechnic Institute and State University used fixed-site, long-term acoustical monitoring near cave systems and along mountain ridgelines and adjacent side slopes in Virginia and West Virginia to determine the timing of hibernation and migratory pulses for the endangered Indiana bat, threatened northern long-eared bat, and eastern red bat. Activities related to date, hourly wind speeds, and ambient temperatures are being analyzed to determine drivers of activity in autumn and spring. These data provide further evidence that operational mitigation strategies at wind energy facilities could help protect migratory bat species and could be used to inform siting decisions for proposed wind energy facilities to lessen the potential impacts on migratory bats that use Appalachian ridges as their primary migration corridors.

Photograph by Mona Khalil, U.S. Geological Survey.

Big brown bat, Rock Creek Park, Washington, D.C.

Contact

W. Mark Ford, USGS Virginia Cooperative Fish and Wildlife Research Unit, wmford@vt.edu, (540) 231–5927

Publication

Muthersbaugh, M.S., 2018, Seasonal activity patterns of bats in the central Appalachian: Blacksburg, Virginia Polytechnic Institute and State University, M.S. Thesis, 219 p.

4. Mid-Atlantic Coastal Bat and Acoustic Nano-Tag Study

Scientists from the Virginia Department of Game and Inland Fisheries, USGS, and Virginia Polytechnic Institute and State University are studying migration timing and habitat use of eastern red bats in coastal areas of Virginia. With the move to develop coastal wind energy resources, there is a need to understand the potential for migration disruption and possible additive mortality of red bats and other migratory species. By understanding the timing of migration and offshore movements of these bats, it may be possible to design and implement wind energy mitigation measures, such as seasonal curtailment and (or) siting, to minimize interactions with bats. Eastern red bats along the coast of Virginia, Maryland, and New Jersey are being captured and outfitted with very high-frequency nano-tags. Fixed sensor towers capable of tracking multiple bats simultaneously have been placed along the Virginia outer coast and in the Chesapeake Bay. Initial results regarding nano-tag retention time and bat migratory movements are being analyzed.

Photograph by Mona Khalil, U.S. Geological Survey.

Eastern red bat caught by a mist net at Rock Creek Park, Washington, D.C.

Contact

W. Mark Ford, USGS Virginia Cooperative Fish and Wildlife Research Unit, wmford@vt.edu, (540) 231–5927

5. Post-White-Nose Syndrome Assessment of Bat Distribution in the Mid-Atlantic and Northeast

The USGS and Virginia Polytechnic Institute and State University, in cooperation with the USFWS, the National White-Nose Syndrome (WNS) Program, the National Park Service, the U.S. Army, the U.S. Marine Corps, Virginia Department of Game and Inland Fisheries, and the National Council for Air and Stream Improvement are using multiyear acoustic data from more than 1,200 locations from the Appalachian Mountains to the Atlantic Coast, and from Virginia to New England, to determine post-WNS distribution and the community structure of bats. These data are being used to model current and future potential occupancy from the individual forest to landscape level. Results can be used to inform managers and regulators of the likelihood that a rare, threatened, or endangered bat species may be found in or near wind energy development, surface mining, or oil and gas development activities on public lands. This project can also provide information on the level of effort required for acoustic monitoring of the endangered Indiana bat and threatened northern long-eared bat.

Contact

W. Mark Ford, USGS Virginia Cooperative Fish and Wildlife Research Unit, wmford@vt.edu, (540) 231–5927

Publications

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Powers, K.E., Reynolds, R.J., Orndorf, W., Ford, W.M., and Hobson, C.S., 2015, Post-white-nose syndrome trends in Virginia's cave bats, 2008–2013: Journal of Ecology and the Natural Environment, v. 7, no. 4, p. 113–124, https://doi.org/10.5897/jene2015.0507.

6. Using Genetic Tools to Examine the Biology of Summer-Roosting Indiana Bats

Wide-ranging populations of Indiana bats have declined by approximately half since 1967, when the species was listed as endangered under the Endangered Species Act. Recent advances in genetic techniques have made it possible to uniquely identify animals using DNA in mark-recapture studies. USGS research has shown that DNA can be extracted from Indiana bat fecal pellets collected beneath roost trees. It is now possible to determine the relatedness of Indiana bat-colony members using genetic information and to estimate population sizes using DNA. Accurate demographic and relatedness information can assist conservation managers in management and recovery of the Indiana bat.

Photograph by Ann Forschauer, U.S. Fish and Wildlife Service.

Indiana bats.

Contact

Sara Oyler-McCance, USGS Fort Collins Science Center, sara_oyler-mccance@usgs.gov, (970) 226–9197

Publication

Oyler-McCance, S.J., Fike, J.A., Lukacs, P.M., Sparks, D.W., O'Shea, T.J., and Whitaker, J.O., Jr., 2018, Genetic mark-recapture improves estimates of maternity colony size for Indiana bats: Journal of Fish and Wildlife Management, v. 9, no. 1, p. 25–35, https://doi.org/10.3996/122016-JFWM-093.

7. Modeling Foraging Habitat Suitability of the Hawaiian Hoary Bat

USGS and University of Hawai‘i at Hilo scientists are using thermal videography and echolocation sampling methods to more directly determine the occurrence and activity of the endangered Hawaiian hoary bat, a tree-roosting species. Previous approaches have relied solely on acoustic detection or bat capture, methods that have been inefficient for use in detecting sparsely distributed and vocally cryptic individuals at locations where encounter rates are low. Foraging habitat suitability is being related to bat occurrence, the frequency of feeding events, and insect abundance using multistate occupancy models, which can be more informative than simple models of presence and assumed absence. This approach may allow managers to evaluate the relative importance of different areas to foraging bats and track the effects of habitat restoration efforts over time.

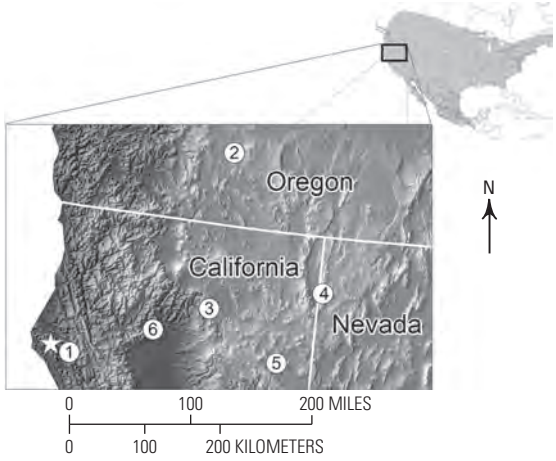
Contact

Marcos Gorresen, USGS Pacific Island Ecosystems Research Center, mgorresen@usgs.gov, (808) 985–6407

Bat Behavior Near Wind Turbines

8. Understanding and Reducing Bat Fatalities Associated With Wind Turbines

Migratory bat species that roost in trees, or tree bats, are disproportionately affected by wind turbines, in part because they appear to be attracted to these structures. USGS science has led to new discoveries about these species, such as the consistent patterns in which tree bats approach and interact with turbines at night. USGS scientists have also identified areas of the continent where mortality risk might be higher, such as the Great Plains, the Great Lakes region, and areas adjacent to coastal wintering areas. Currently, USGS scientists are using this new information about bat behaviors, seasonal distribution, and perception to develop efficient and effective ways of reducing bat interactions with wind turbines.



Locations of a free-ranging hoary bat recorded using a miniature Global Positioning System tag in October 2014 (from Weller and others, 2016).

Contact

Paul Cryan, USGS Fort Collins Science Center, cryanp@usgs.gov, (970) 226–9389

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9. Factors Associated With Bat Mortality at Wind Energy Facilities in the United States

Researchers conducted a synthesis of studies on bat collision mortality with wind turbines and found further evidence that collision mortality is greatest for migratory tree-roosting species, such as the hoary bat, eastern red bat, and silver-haired bat. Researchers reviewed 218 studies conducted at 100 wind energy facilities in North America. The amount of grassland near the facility best predicted and was inversely related to bat mortality; however, further representative sampling of wind energy facilities is required to validate this pattern. This synthesis is a resource that developers and resource managers can consider when determining the placement of wind energy facilities.

Contact

Jay Diffendorfer, USGS Geosciences and Environmental Change Science Center, jediffendorfer@usgs.gov, (303) 236–5369

Publication

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10. Wind Energy Effects on Mexican Free-Tailed Bats

USGS scientists and collaborators at the University of Arizona are studying the interactions of Mexican free-tailed bats (MFTB) with wind energy facilities and how bat fatalities at wind energy facilities may influence pest control services provided by MFTB to farmers in the Southwest. Scientists are using seasonal distribution models of MFTB and a full life cycle demographic model as well as data about roost locations, known wind turbine locations and bat fatalities, and locations of cotton, corn, and sorghum crops to address this question.

Contact

Jay Diffendorfer, USGS Geosciences and Environmental Change Science Center, jediffendorfer@usgs.gov, (303) 236–5369
Darius Semmens, USGS Geosciences and Environmental Change Science Center, dsemmens@usgs.gov, (303) 236–1420

Publications

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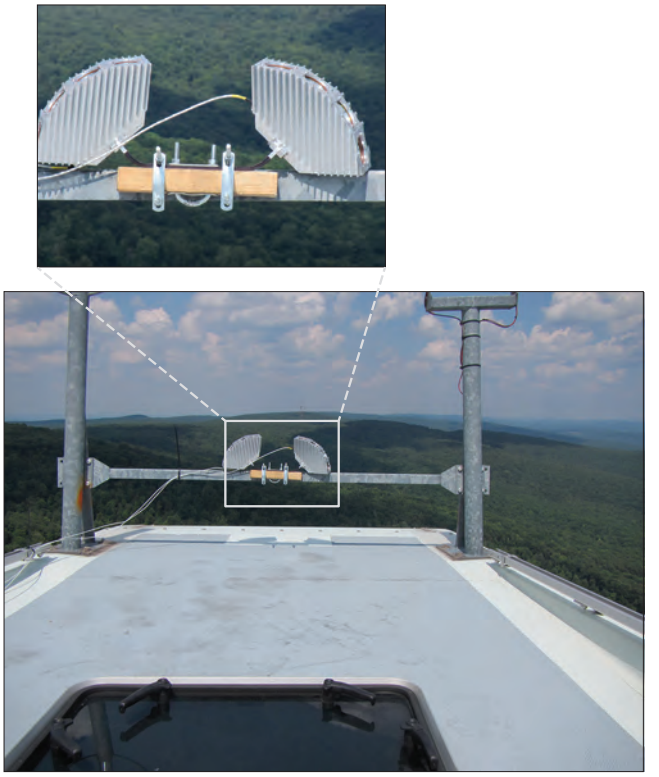
Bat Deterrents and Wind Turbine Operational Curtailment

11. Ultraviolet Illumination as a Means of Reducing Bat Activity and Risk at Wind Turbines

Insectivorous bats are known for their ability to find and pursue flying insect prey at close range using echolocation, but they also rely heavily on vision. Using a cue that only bats would perceive, the USGS is developing technologies to prevent bats from approaching wind turbines that might be mistaken for trees. USGS scientists are collaborating with the National Renewable Energy Laboratory through a U.S. Department of Energy (DOE) Technology Development and Innovation award (https://www.nrel.gov/news/program/2018/nrel-announces-new-technology-development-and-innovation-project-selections.html) on refining a selectively perceptible wind turbine system to prevent bat fatalities. This project plans to test the hypothesis that dim, flickering, and position-shifting ultraviolet (UV) light can enable bats to differentiate turbines from trees, keeping bats from approaching turbines in search of resources such as food or roosts. Results from this and related research may determine whether dim UV light can reduce bat activity and fatality at operational wind farms, with the potential benefit of allowing operators to run turbines at maximum efficiency.



Photographs by Paul Cryan, U.S. Geological Survey.

A UV emitter mounted atop a turbine and tested in Pennsylvania.

Contacts

Paul Cryan, USGS Fort Collins Science Center, cryanp@usgs.gov, (970) 226–9389
Marcos Gorresen, USGS Pacific Island Ecosystems Research Center, mgorrensen@usgs.gov, (808) 985–6407

Publications

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12. Wind Turbine Curtailment Strategies to Reduce Bat Fatality

Wildlife fatalities due to collisions with wind turbines have sparked efforts to reduce the number of fatalities through operational management. Recent studies have shown that altering turbine operations when winds are below certain speeds can decrease the number of bat fatalities, but questions remain regarding optimal management. The USGS and colleagues are modeling the proportion of bat fatalities occurring under varying meteorological conditions at Avangrid Renewables' Blue Creek Wind Farm in Ohio to identify conditions that minimize both bat fatalities and energy production loss. USGS scientists are also investigating whether accurate and precise estimates of fatalities can be derived from carcass searches conducted at easily accessed areas, such as roads and pads beneath turbines.

Contact

Manuela M. Huso, USGS Forest and Rangeland Ecosystem Science Center, mhuso@usgs.gov, (541) 750–0948

13. Comparing the Effectiveness of Acoustic Deterrents to Operational Curtailment in Reducing Bat Fatality

Independent studies have shown that both operational curtailment and ultrasonic acoustic deterrents can be effective in reducing bat fatalities at wind energy facilities. A primary goal of this study, co-funded by the DOE, USGS, and Bat Conservation International (BCI), is to compare the costs and benefits of acoustic deterrents to operational curtailment. Fatality rates, when both curtailment and acoustic deterrents are applied singly and in combination, are being compared with fatality rates at untreated turbines to determine if one of these methods is more effective, if they are equally effective, or if they might act synergistically when employed simultaneously.

Contact

Manuela M. Huso, USGS Forest and Rangeland Ecosystem Science Center, mhuso@usgs.gov, (541) 750–0948

Photograph by Paul Cryan, U.S. Geological Survey.

Wind turbine bat fatality.

Additional Publications About Bats

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Raptors

Photograph from Pixabay, morfar, Creative Commons CC0.

White-tailed sea eagle.

Golden and Bald Eagles

14. Golden Eagle Migration and Habitat Use

The USGS is collecting information related to habitat use, home range, and population dynamics of golden eagles in the Central Appalachians, northeastern California, and the Mojave and Sonoran Deserts, using various methodologies including Global Positioning System-Global System for Mobile (GPS-GSM) communications telemetry, standard geographic information system (GIS) analyses, nest visits, and non-invasive genetic monitoring. The data have been used to model movement and create risk models to assist resource management agencies in evaluating management options for this species. Results can inform resource managers about where and when eagles could be most at risk from disturbances associated with renewable energy structures. Data are being combined with datasets from similar projects to create a framework and baseline to build an effective long-term golden eagle monitoring program in support of adaptive management.

Photograph from U.S. Geological Survey.

Golden eagle with a GPS backpack.

Contact

Todd E. Katzner, USGS Forest and Rangeland Ecosystem Science Center, tkatzner@usgs.gov, (208) 426–5232

Publications

Brown, J.L., Bedrosian, B., Bell, D.A., Braham, M.A., Cooper, J., Crandall, R.H., DiDonato, J., Domenech, R., Duerr, A.E., Katzner, T.E., Lanzone, M.J., LaPlante, D.W., McIntyre, C.L., Miller, T.A., Murphy, R.K., Shreading, A., Slater, S.J., Smith, J.P., Smith, B.W., Watson, J.W., and Woodbridge, B., 2017, Patterns of spatial distribution of golden eagles across North America—How do they fit into existing landscape-scale mapping systems?: Journal of Raptor Research, v. 51, no. 3, p. 197–215, https://doi.org/10.3356/JRR-16-72.1.

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15. Assessing Eagle Use Frequency at Wind Energy Facilities

Operation of wind energy facilities can adversely affect eagles, among other wildlife. USFWS guidelines suggest wind facility operators or developers survey eagle use and calculate the risk to eagles across the project area; however, questions have arisen concerning the degree to which data from survey plots represent eagle use over an entire project area. The USGS is using existing telemetry data on golden eagles in the Mojave Desert, California, to help the USFWS compare eagle use within a plot to eagle use over an entire project area. Results can provide a better understanding of golden eagle activity and a context for interpreting survey data collected at potential wind energy facilities.

Contact

Todd E. Katzner, USGS Forest and Rangeland Ecosystem Science Center, tkatzner@usgs.gov, (208) 426–5232

Publication

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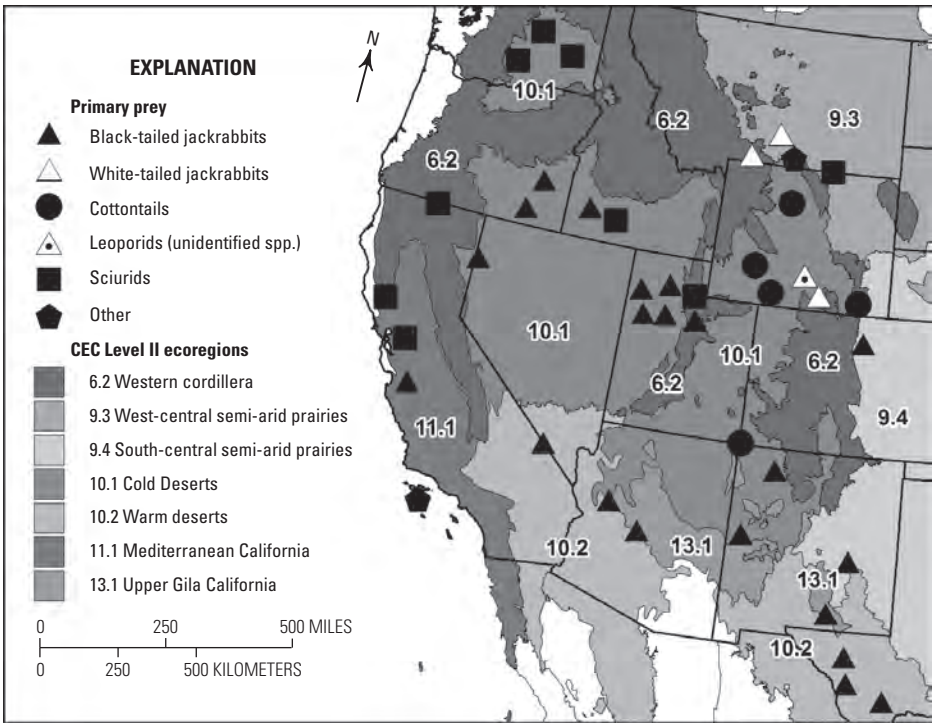
Photograph by Brian Millsap, U.S. Fish and Wildlife Service.

Golden eagle in flight.

16. Linking Habitat and Prey Availability to Golden Eagle Ecology

Researchers gathered and compiled data on golden eagle diets to summarize and compare prey diversity across the West and Desert Southwest and construct predictive models that link prey availability and abundance with eagle productivity and survival. Golden eagle diets differed among ecosystems: lower prey diversity was associated with desert and shrub-steppe and higher prey diversity was associated with mountain ranges and the Columbia Plateau. Detailed information about golden eagle prey can help prioritize prey management and develop conservation strategies.



Primary prey of golden eagles during the breeding season. Map labels correspond to the prey group identified most for each study area. Map numbers correspond to Commission for Environmental Cooperation (CEC) Level II Ecoregions (CEC, 2016). Study locations were adjusted to be distinguishable at this scale.

Contacts

Todd Esque, USGS Western Ecological Research Center, tesque@usgs.gov, (702) 564–4506
Kathleen Longshore, USGS Western Ecological Research Center, longshore@usgs.gov, (702) 564–4505

Publications

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17. Spatial Patterns in Golden Eagle Occupancy and Reproduction

USGS scientists and partners investigated spatial patterns in occupancy and breeding success of golden eagles in the Diablo Range, California, from 2014 to 2016, a period of exceptional drought. This approach to mapping and quantifying site quality may offset the impacts of increasing human land use and development by helping managers prioritize compensation measures for golden eagles.

Contact

J. David Wiens, USGS Forest and Rangeland Ecosystem Science Center, jwiens@usgs.gov, (541) 750–0961

Publication

Wiens, J.D., Kolar, P.S., Hunt, W.G., Hunt, T., Fuller, M.R., and Bell, D.A., 2018, Spatial patterns in occupancy and reproduction of golden eagles during drought—Prospects for conservation in changing environments: The Condor, v. 120, no. 1, p. 106–124, https://doi.org/10.1650/CONDOR-17-96.1.

18. Population Demography of Golden Eagles Near Altamont Pass, California

Wind turbines at the Altamont Pass Wind Resource Area in California have been estimated to cause fatalities of as many as 28 to 68 golden eagles annually. This study investigates how estimated levels of turbine-related mortality and other environmental stressors may interact to affect the population demography of golden eagles in the broader landscapes surrounding the wind farm. The USGS and partners are using historic and current eagle data to assess territory occupancy, abundance, breeding success, survival, and habitat use of different age classes of golden eagles. This information has been used to quantify how the local population of golden eagles may respond to observed levels of turbine-related fatalities. Additionally, results from this study are providing detailed information on specific sites or breeding areas that contribute most to overall population growth, which permits land managers to identify and prioritize important areas for conservation.

Contact

J. David Wiens, USGS Forest and Rangeland Ecosystem Science Center, jwiens@usgs.gov, (541) 750–0961

Publications

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Photograph by Todd Katzner, U.S. Geological Survey.

Wind turbines at the Altamont Pass Wind Energy Facility, Altamont, California.

19. Golden Eagle Monitoring Plan for the Desert Renewable Energy Conservation Plan Area

The Desert Renewable Energy Conservation Plan (DRECP) was developed to provide protection of Mojave and Colorado Desert ecosystems while allowing for the appropriate development of renewable energy projects. The USGS and partners developed a research and monitoring plan for the DRECP that profiles the ecology and status of golden eagles and their habitats in the area, provides a range of potential sampling options to address monitoring needs, and characterizes an iterative approach to monitoring golden eagles focusing on links between changes in human land-use, nesting, and foraging habitat conditions and population dynamics. A new report outlines options for monitoring the status and population trends of golden eagles in southern California. The adaptive, multiscale scheme of the monitoring framework provides decision makers with a periodic, scientifically rigorous evaluation of the status of golden eagles in the DRECP area and can provide regulatory agencies with information to make conservation policy decisions regarding permitting and siting of renewable energy projects.

Contact

J. David Wiens, USGS Forest and Rangeland Ecosystem Science Center, jwiens@usgs.gov, (541) 750–0961

Publications

California Energy Commission, 2018, Energy Research and Development Division final project report—Golden eagle monitoring plan for the Desert Renewable Energy Conservation Plan: Sacramento, Calif., California Energy Commission: Prepared by U.S. Geological Survey Forest and Rangeland Ecosystem Science Center, CEC–500–2018–008, [Contract Number: 500–12–007], 98 p., http://www.energy.ca.gov/publications/displayOneReport.php?pubNum=CEC-500-2018-008.

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20. Golden Eagle Movement and Conservation in Coastal Southern California

To evaluate the effects of human activities on golden eagles in coastal southern California, the USGS began a multiyear golden eagle survey and tracking program in 2014, supported by the San Diego Association of Governments, California Department of Fish and Wildlife, the USFWS, and the BLM. More than 40 golden eagles were captured in San Diego County, Orange County, and western Riverside County, California, and fitted with GPS backpack transmitters, allowing scientists to track their movements. Movements ranged as far north as northern Nevada and southern Wyoming and as far south as the southern tip of Baja California, Mexico. Researchers also developed habitat selection models and provided predictions of population-level habitat selection for golden eagles in San Diego County. Modeled results indicate strong avoidance of urban areas, moderate avoidance of exurban areas, and avoidance of a buffer around these landscapes. In contrast, eagles preferred more rugged areas in higher elevation terrain. This work contributes to a broader understanding of the population status, demography, resource use, and genetic structure of golden eagles across a wide gradient of environmental conditions.

Contacts

Robert N. Fisher, USGS Western Ecological Research Center, rfisher@usgs.gov, (619) 225–6422
Melanie Madden, USGS Western Ecological Research Center, mmadden@usgs.gov, (619) 225–6450
Jeff Tracey, USGS Western Ecological Research Center, jtracey@usgs.gov, (619) 225–6457

Publications

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21. Golden Eagles in New Mexico

The BLM manages large areas in New Mexico that have a high potential for wind energy development. USGS science is helping assess the risk that proposed wind energy developments in southeastern and south-central New Mexico may have on resident and migratory golden eagles. The study was conducted to assess the movement ecology and genetic structure of migratory and resident golden eagles; identify nest sites; estimate productivity and survival, origin, and migration patterns; and determine factors affecting golden eagle distribution. Results of the study may be used to inform the development of mitigation strategies that can reduce potential negative effects from proposed wind energy developments on golden eagles.

Contact

James Cain III, USGS New Mexico Cooperative Fish and Wildlife Research Unit, jwcain@usgs.gov, (575) 646–3382

Publication

Doyle, J.M., Katzner, T.E., Roemer, G.W., Cain, J.W., Millsap, B.A., McIntyre, C.L., Sonsthagen, S.A., Fernandez, N.B., Wheeler, M., Bulut, Z., Bloom, P.H., and DeWoody, J.A., 2016, Genetic structure and viability selection in the golden eagle (*Aquila chrysaetos*), a vagile raptor with a Holarctic distribution: Conservation Genetics, v. 17, no. 6, p. 1307–1322, https://doi.org/10.1007/s10592-016-0863-0.

22. Wintering Distribution of Golden Eagles in the Southern Great Plains

The Southern Great Plains, which comprises eastern New Mexico and the panhandles of Oklahoma and Texas, is experiencing rapid wind energy development. The region has traditionally been an important wintering area for golden eagles. The USGS is assessing the distribution and abundance of wintering golden eagles in relation to land-cover and land-use types across the region. The results of this study can provide industry managers with insight into whether landscape features pose potential conflicts between wind energy development and eagles.

Photograph from U.S. Geological Survey.

Dr. Clint Boal, Texas Cooperative Fish and Wildlife Research Unit, observing a golden eagle nest in the caprock canyon country of west Texas.

Contact

Clint Boal, USGS Texas Cooperative Fish and Wildlife Research Unit, cboal@usgs.gov, (806) 834–6536

Publication

Mitchell, N.R., 2017, Assessment of golden eagles in the southern Great Plains and Trans Pecos regions: Lubbock, Texas Tech University, M.S. Thesis, 96 p., http://hdl.handle.net/2346/72725.

23. Tracking Bald Eagles Near Wind Energy Facilities in the Central Great Plains

The Central Great Plains is an important focus area for the development of new wind facilities. The USGS is leading an effort to track bald eagles using GPS-GSM telemetry to acquire information that will help wildlife managers address potential conflict between bald eagles and wind turbines in Oklahoma and collaborate on similar work in Iowa and Illinois. Scientists are collecting information on topography, weather, and land cover to understand how environmental conditions may put eagles at risk from collisions with turbines.

Contact

Todd E. Katzner, USGS Forest and Rangeland Ecosystem Science Center, tkatzner@usgs.gov, (208) 426–5232

24. Using Drones to Detect Golden Eagle Carcasses

The USGS, in collaboration with Oregon State University and the Confederated Tribes of Warm Springs, is investigating the use of unmanned aircraft systems, or drones, to detect golden eagle carcasses at wind energy facilities. Research objectives are to use change-detection software to compare ground images taken by drones on separate flights over time to detect the timing of carcass appearance and to evaluate whether detection is affected by vegetation or carcass size.

Contact

Manuela M. Huso, USGS Forest and Rangeland Ecosystem Science Center, mhuso@usgs.gov, (541) 750–0948

Testing drones as a tool for detecting eagle carcasses.

Photograph by Manuela Huso, U.S. Geological Survey.

Other Raptors

25. Condor Flight Behavior Near Wind Energy Facilities

Scientists from the USGS, USFWS, California Department of Fish and Wildlife, and BLM are using high-frequency GPS-GSM telemetry to study flight responses of California condors to understand the risk these raptors face from potential wind energy development. Tracking 24 condors for nearly 2 years, researchers found that although the condors only occasionally flew at altitudes in the rotor-swept zone of turbines, they regularly used classes of winds preferred by wind energy developers. The collision risk to large soaring birds from turbines should be relatively lower over flatter, less rugged areas and in habitat used during daytime soaring. This information can be used by wind energy developers to predict and avoid the risk to condors from existing and proposed turbines.

Contact

Todd E. Katzner, USGS Forest and Rangeland Ecosystem Science Center, tkatzner@usgs.gov, (208) 426–5232

Publications

Poessel, S.A., Brandt, J., Mendenhall, L., Braham, M.A., Lanzone, M.J., McGann, A.J., and Katzner, T.E., 2018, Flight response to spatial and temporal correlates informs risk from wind turbines to the California condor: The Condor, v. 120, no. 2, p. 330–342, https://doi.org/10.1650/CONDOR-17-100.1.

Poessel, S.A., Brandt, J., Miller, T.A., and Katzner, T.E., 2018, Meteorological and environmental variables affect flight behaviour and decision-making of an obligate soaring bird, the California Condor *Gymnogyps californianus*: Ibis, v. 160, no. 1, p. 36–53, https://doi.org/10.1111/ibi.12531.

California condor.

Photograph from U.S. Fish and Wildlife Service.

26. Raptor Nest-Site Use in Relation to Proximity to Coalbed-Methane Development in Wyoming

Coalbed-methane (CBM) extraction is a major land use in Wyoming, and resource managers are concerned that some raptor species may be vulnerable to habitat changes caused by CBM development given the ecological requirements and population trajectories of these birds. To determine whether the 805-meter buffer around development sites implemented by the BLM is biologically meaningful in terms of raptor responses and sufficient as a protective measure, USGS scientists used data collected in the observation of nests of 12 raptor species across 9 years (2003–11) in the Powder River Basin, Wyoming, in relation to CBM development. Red-tailed hawks, burrowing owls, and long-eared owls used nests in undeveloped areas, specifically nests near CBM development, more than nests in developed areas. Although findings suggest potential avoidance of nesting in areas near CBM development by these species, other factors such as habitat preference, local prey availability, raptor density, and weather may also play a role.

Contact

Anna D. Chalfoun, USGS Wyoming Cooperative Fish and Wildlife Research Unit, achalfoun@usgs.gov, (307) 766–6966

Publication

Carlile, J.D., Sanders, L.E., Chalfoun, A.D., and Gerow, K.G., 2018, Raptor nest-site use in relation to the proximity of coalbed methane development: Animal Biodiversity and Conservation, v. 41, no. 2, p. 227–243, http://abc.museucienciesjournals.cat/files/ABC_41-2_pp_227-243.pdf.

27. Potential Interactions of Migrating Raptors and Wind Energy Sites at the International Scale

Swainson's hawks are long-distance migratory raptors that breed across Western North America and migrate to Argentina for the winter. This annual round trip of approximately 20,000 kilometers, or 12,500 miles, takes the hawks over 12 countries, which all have interests in wind energy development. The USGS is using GPS transmitters to determine the hawk's precise migration routes and movement patterns in their breeding and wintering ranges. This research can help identify high-risk areas for migrating raptors at the international scale.

Photograph by Tom Koerner, U.S. Fish and Wildlife Service.

Swainson's hawk, Seedskadee National Wildlife Refuge, Wyoming.

Contact

Clint Boal, USGS Texas Cooperative Fish and Wildlife Research Unit, cboal@usgs.gov, (806) 742–2851

Publication

Watson, K.A., Boal, C.W., Groen, L.M., and Walker, J.R., 2017, Using GPS transmitters to explore movement ecology and to assess risk of the wind energy industry for Swainson's hawks: U.S. Department of Energy Office of Scientific and Technical Information, Technical Report IROS–655, 86 p., https://doi.org/10.2172/1408777.

Additional Publications About Raptors

Golden Eagles Behavior, Ecology, and Distribution

Tack, J.D., Noon, B.R., Bowen, Z.H., Strybos, L., and Fedy, B.C., 2017, No substitute for survival—Perturbation analyses using a golden eagle population model reveals limits to managing for take: Journal of Raptor Research, v. 51, no. 3, p. 258–272, https://doi.org/10.3356/JRR-16-32.1.

Mallon, J.M., Bildstein, K.L., and Katzner, T.E., 2016, In-flight turbulence benefits soaring birds: The Auk, v. 133, no. 1, p. 79–85, https://doi.org/10.1642/auk-15-114.1.

Braham, M., Miller, T., Duerr, A.E., Lanzone, M., Fesnock, A., LaPre, L., Driscoll, D., and Katzner, T., 2015, Home in the heat—Dramatic seasonal variation in home range of desert golden eagles informs management for renewable energy development: Biological Conservation, v. 186, p. 225–232, https://doi.org/10.1016/j.biocon.2015.03.020.

Tack, J.D., and Fedy, B.C., 2015, Landscapes for energy and wildlife—Conservation prioritization for golden eagles across large spatial scales: PLOS ONE, v. 10, no. 8, e0134781, https://doi.org/10.1371/journal.pone.0134781.

Golden Eagle Genetics

Craig, E.H., Adams, J.R., Waits, L.P., Fuller, M.R., and Whittington, D.M., 2016, Nuclear and mitochondrial DNA analyses of golden eagles (*Aquila chrysaetos canadensis*) from three areas in western North America—Initial results and conservation implications: PLOS ONE, v. 11, no. 10, e0164248, https://doi.org/10.1371/journal.pone.0164248.

Doyle, J.M., Katzner, T.E., Roemer, G.W., Cain, J.W., Millsap, B.A., McIntyre, C.L., Sonsthagen, S.A., Fernandez, N.B., Wheeler, M., Bulut, Z., Bloom, P.H., and DeWoody, J.A., 2016, Genetic structure and viability selection in the golden eagle (*Aquila chrysaetos*), a vagile raptor with a Holarctic distribution: Conservation Genetics, v. 17, no. 6, p. 1307–1322, https://doi.org/10.1007/s10592-016-0863-0.

Survey, Monitoring, and Siting Tools

Skipper, B.R., Boal, C.W., Tsai, J.-S., and Fuller, M.R., 2017, Assessment of frequency and duration of point counts when surveying for golden eagle presence: Wildlife Society Bulletin, v. 41, no. 2, p. 212–223, https://doi.org/10.1002/wsb.770.

Jachowski, D.S., Katzner, T., Rodrigue, J.L., and Ford, W.M., 2015, Monitoring landscape-level distribution and migration phenology of raptors using a volunteer camera-trap network: Wildlife Society Bulletin, v. 39, no. 3, p. 553–563, https://doi.org/10.1002/wsb.571.

New, L., Bjerre, E., Millsap, B., Otto, M.C., and Runge, M.C., 2015, A collision risk model to predict avian fatalities at wind facilities—An example using golden eagles, *Aquila chrysaetos*: PLOS ONE, v. 10, no. 7, e0130978, https://doi.org/10.1371/journal.pone.0130978.

Condor Movement and Space Use

Rivers, J.W., Johnson, J.M., Haig, S.M., Schwarz, C.J., Burnett, L.J., Brandt, J., George, D., and Grantham, J., 2014, An analysis of monthly home range size in the critically endangered California condor *Gymnogyps californianus*: Bird Conservation International, v. 24, no. 4, p. 492–504, https://doi.org/10.1017/s0959270913000592.

Rivers, J.W., Johnson, J.M., Haig, S.M., Schwarz, C.J., Burnett, L.J., Brandt, J., George, D., and Grantham, J., 2014, An analysis of monthly home range size in the critically endangered California condor *Gymnogyps californianus*–CORRIGENDUM: Bird Conservation International, v. 25, no. 2, p. 258, https://doi.org/10.1017/s0959270915000039.

Tracey, J.A., Sheppard, J., Zhu, J., Wei, F., Swaisgood, R.R., Fisher, R.N., and Sueur, C., eds., 2014, Movement-based estimation and visualization of space use in 3D for wildlife ecology and conservation: PLOS ONE, v. 9, no. 7, e101205, https://doi.org/10.1371/journal.pone.0101205.

Great Lakes, Coastal, and Marine Birds

Photograph from U.S. Fish and Wildlife Service.

A common loon on Lake Michigan.

Great Lakes

28. Monitoring and Mapping Avian Resources in Nearshore and Open Waters of Lake Michigan

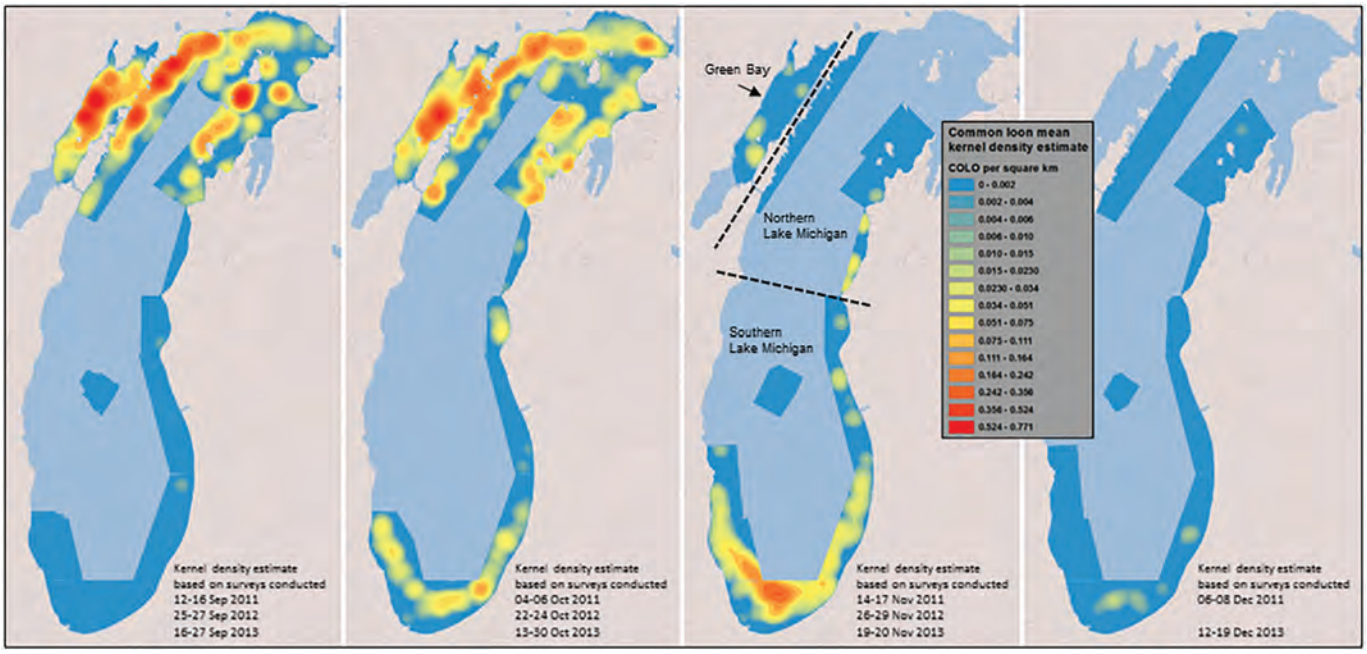
USGS scientists have surveyed pelagic bird use in areas of Lake Michigan during fall and winter periods over 4 years to determine distribution patterns and abundance in nearshore and open water areas for the common loon, red-throated loon, white-winged scoter, black scoter, surf scoter, long-tailed duck, common merganser, red-breasted merganser, red-necked grebe, horned grebe, greater scaup, lesser scaup, and other waterbirds. Efforts are now focused on developing spatially explicit distribution models from aerial survey data of selected waterbirds on Lake Michigan. These data can help resource managers with energy development planning and siting decisions.

Contact

Kevin P. Kenow, USGS Upper Midwest Environmental Sciences Center, kkenow@usgs.gov, (608) 781–6278

29. Documenting Movements, Habitat Use, and Foraging Patterns of Common Loons and Long-Tailed Ducks

USGS scientists are using satellite telemetry and archival geolocator tags to document the movements, habitat use, and foraging patterns of common loons during migration across the Great Lakes. Additional work is underway to radio-mark long-tailed ducks to determine their local movement patterns while wintering at Lake Michigan. These data on waterbird seasonal movement patterns and core use areas can be used to inform environmental impact assessments of potential wind turbine placement and assist managers to identify, evaluate, and suggest alternate wind facility sites in the Great Lakes.



Distribution and foraging patterns of common loons on Lake Michigan.

Contact

Kevin P. Kenow, USGS Upper Midwest Environmental Sciences Center, kkenow@usgs.gov, (608) 781–6278

Publication

Kenow, K.P., Houdek, S.C., Fara, L.J., Gray, B.R., Lubinski, B.R., Heard, D.J., Meyer, M.W., Fox, T.J., and Kratt, R.J., 2018, Distribution and foraging patterns of common loons on Lake Michigan with implications for exposure to type E avian botulism: Journal of Great Lakes Research, v. 44, no. 3, p. 497–513, https://doi.org/10.1016/j.jglr.2018.02.004.

Photograph by Judith Bloom, U.S. Geological Survey volunteer.

A juvenile common loon wearing a satellite transmitter antenna follows an adult at Tomahawk Lake, Wisconsin.

30. Airspace Use by Migrating Landbirds at Lake Erie

Interest is growing in developing wind energy capacity along Great Lakes shorelines, both on and offshore. The potential impacts to the large concentrations of landbirds that use the southern Lake Erie shoreline during spring and fall migration need to be considered in this development. Two marine radars, operated simultaneously at the shoreline and sites 5 or 24 kilometers inland, are collecting data that can be used to describe movement patterns of night-migrating landbirds. USGS scientists are estimating the ascent and descent flight profiles for night-migrating landbirds in relation to distance from the southwestern Lake Erie shoreline. Scientists are also estimating the intensity of nightly bird movements and relating those results to data on banded birds.

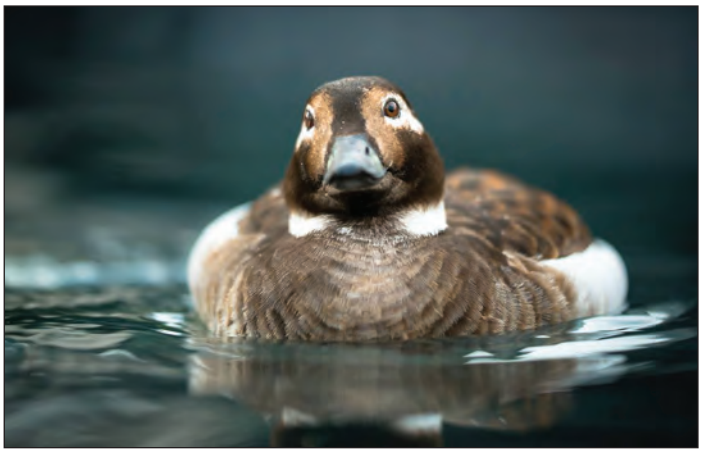
Contact

Eileen M. Kirsch, USGS Upper Midwest Environmental Sciences Center, ekirsch@usgs.gov, (608) 781–6226

Atlantic Ocean

31. Satellite Tracking Offshore Habitat Use in Diving Bird Species

In collaboration with BOEM, USFWS, and other partners, USGS scientists are using platform terminal transmitter satellite tracking tags to determine the occurrence and local movement patterns of red-throated loons, surf scoters, and northern gannets in U.S. waters of the mid-Atlantic region during migration and winter. From 2012 to 2016, scientists tracked the movements of 75 gannets and 66 loons, and from 2001 to 2016, scientists tracked 217 scoters on their northward migration to breeding colonies and on southward migration back to and through the mid-Atlantic region. Data can be used to inform siting, permitting, and regulation of future offshore wind development and can provide important information on key habitat use and migration of a suite of species with different ecological niches.



Photograph by Jonathan Fiely, U.S. Geological Survey.

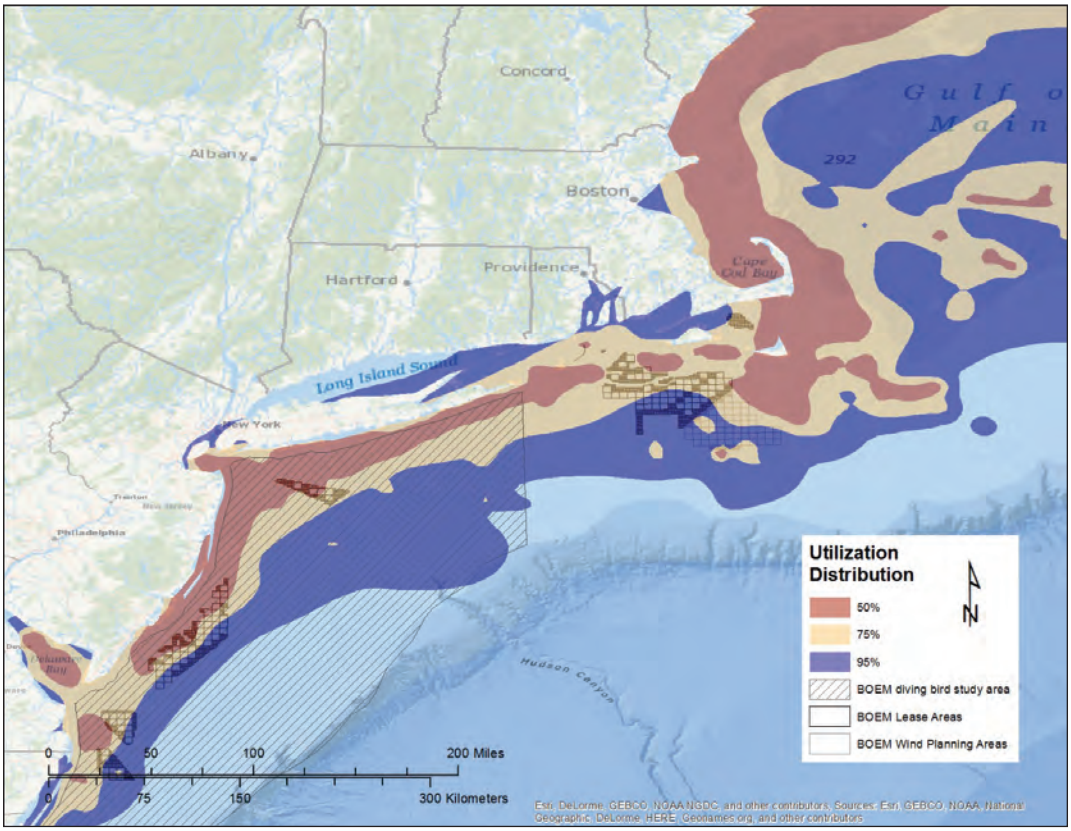
Adult female surf scoter.

Contact

Alicia M. Berlin, USGS Patuxent Wildlife Research Center, aberlin@usgs.gov, (301) 497–5730

Publication

Spiegel, C.S., Berlin, A.M., Gilbert, A.T., Gray, C.O., Montevecchi, W.A., Stenhouse, I.J., Ford, S.L., Olsen, G.H., Fiely, J.L., Savoy, L., Goodale, M.W., and Burke, C.M., 2017, Determining fine-scale use and movement patterns of diving bird species in Federal waters of the Mid-Atlantic United States using satellite telemetry: Sterling, Va., Bureau of Ocean Energy Management Office of Renewable Energy, OCS Study BOEM 2017–069, https://pubs.er.usgs.gov/publication/70194432.



Distributions of adult northern gannets (n = 36) during fall migration in the Mid-Atlantic and southern New England, 2012–15. Intensity of use ranges from lowest areas of use (blue) to greatest areas of use (red) (from Spiegel and others, 2017).

32. External GPS-GSM Transmitters for Tracking Seabirds

USGS scientists are testing solar-powered GPS-GSM transmitters on seabirds to capture fine-scale movement patterns and better relate the influence of weather, resource availability, and hazardous conditions on seabirds. These transmitters are providing data on flight altitude of seabirds, information that is relevant to assessing the risk of collision or displacement to seabirds by potential offshore wind turbines. This information can be used to model habitat use, mortality risk, and the impact of weather on flight behavior for these species regarding multiple proposed offshore wind facilities along the Atlantic coast.

Contact

Alicia M. Berlin, USGS Patuxent Wildlife Research Center, aberlin@usgs.gov, (301) 497–5730

Photograph by Jonathan Fiely, U.S. Geological Survey.

Diving male surf scoter with a newly designed GPS-GSM transmitter.

33. Evaluating Acoustic Sensitivity of Diving Birds to Offshore Energy Development Activities

Diving birds may use auditory cues to aid in orientation, communication, and (or) foraging, but the ability of individuals to hear underwater has not been experimentally tested. Understanding hearing in diving birds is important to current regulatory and management priorities in evaluating the impact of noise pollution, such as offshore energy construction activities, naval sonar activities, and the effectiveness of acoustic deterrents to avoid by-catch of birds in gill nets. USGS scientists are measuring the in-air and underwater auditory thresholds of diving bird species by using behavioral and electrophysiological techniques to test whether diving bird species rely on auditory cues to orient or forage underwater. These studies represent an important development of procedures and equipment that can be used to expand the available data on diving birds; the data can then be applied to evaluate anthropogenic noise sources that may affect diving birds, including underwater offshore energy construction activities, offshore vessel traffic, bathymetric mapping, and sonar.

Contact

Alicia M. Berlin, USGS Patuxent Wildlife Research Center, aberlin@usgs.gov, (301) 497–5730

Photograph from U.S. Geological Survey.

Measuring a northern gannet.

Publications

Crowell, S.E., Wells-Berlin, A.M., Therrien, R.E., Yannuzzi, S.E., and Carr, C.E., 2016, In-air hearing of a diving duck—A comparison of psychoacoustics and auditory brainstem response thresholds: Journal of the Acoustical Society of America, v. 139, no. 5, p. 3001–3008, https://doi.org/10.1121/1.4948574.

Crowell, S.E., Wells-Berlin, A.M., Carr, C.E., Olsen, G.H., Therrien, R.E., Yannuzzi, S.E., and Ketten, D.R., 2015, A comparison of auditory brainstem responses across diving bird species: Journal of Comparative Physiology A, v. 201, no. 8, p. 803–815, https://doi.org/10.1007/s00359-015-1024-5.

34. Possible Displacement of Red-Throated Loons by Wind Energy Development

Major spring and fall staging and stopover locations of red-throated loons, or red-throated divers, along the North American Atlantic Flyway include Nantucket Shoals, the Gulf of Saint Lawrence, Hudson Bay, and the lower Great Lakes. During the nonbreeding season, this species uses marine areas in the North Sea, Irish Sea, and Baltic Sea. These same areas are also bustling with various marine industry activities, including construction and operation of offshore wind farms, which can displace marine birds. The consequences of displacement for individuals and consequently on the population as a whole are unknown. A May 2017 workshop was held in Edinburgh, Scotland, where scientists developed concepts about how red-throated divers might be affected by displacement. A report was published on the main points of discussion and concepts developed during the workshop. This information can help inform project development decisions by stakeholders including BOEM and the wind energy industry.

Photograph by Ryan Askren, U.S. Geological Survey.

A red-throated loon swimming in a lake on the Colville River Delta, Alaska.

Contact

John M. Pearce, USGS Alaska Science Center, jpearce@usgs.gov, (907) 786–7094

Publications

McCloskey S.E., Uher-Koch, B.D., Schmutz J.A., and Fondell, T.F., 2018, International migration patterns of red-throated loons (*Gavia stellata*) from four breeding populations in Alaska: PLOS ONE, v. 13, no. 1, e0189954, https://doi.org/10.1371/journal.pone.0189954.

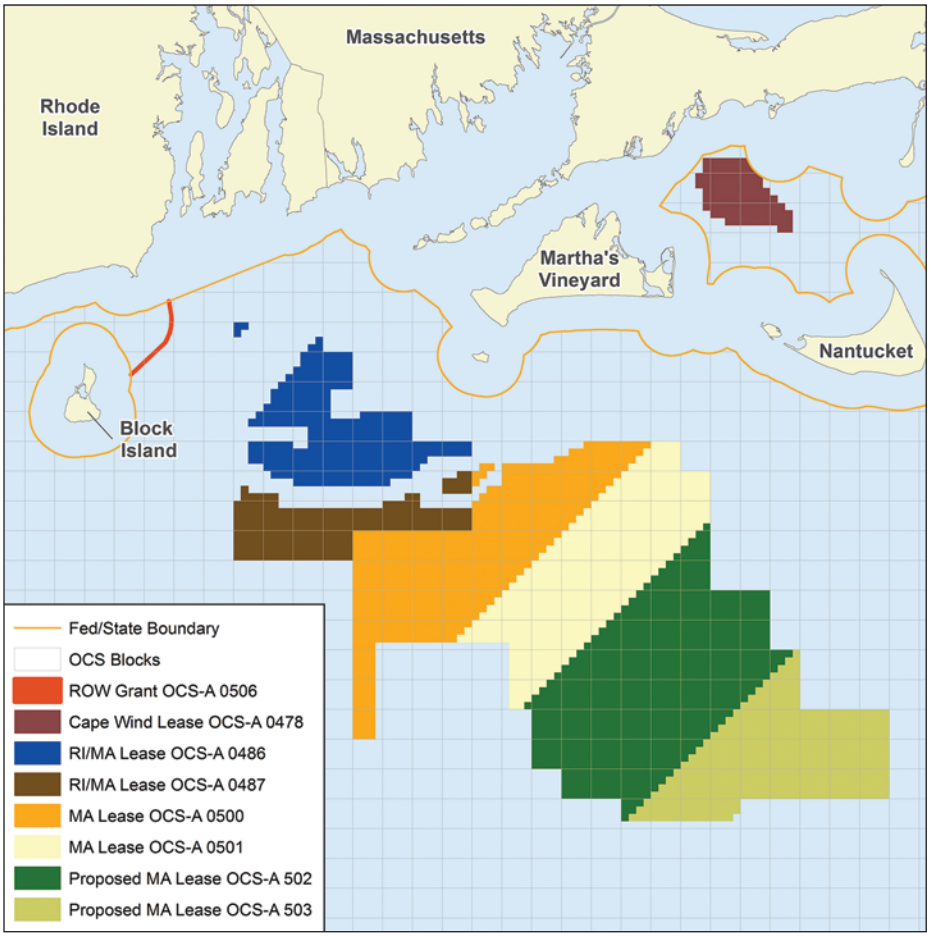
Dierschke, V., Furness, R.W., Gray, C.E., Petersen, I.K., Schmutz, J., Zydelis, R., and Daunt, F., 2017, Possible behavioural, energetic and demographic effects of displacement of red-throated divers: JNCC Report, no. 605, 23 p., https://pubs.er.usgs.gov/publication/70196294.

35. Potential Impacts of Offshore Wind Energy Projects on Endangered Roseate Terns

Offshore wind energy projects are being proposed and developed off the coasts of Massachusetts and New York, with the first project becoming operational at Block Island, off the coast of Rhode Island. Fish-eating terns traveling through these areas could be affected by the construction and operation of wind turbines. The Cape and Islands area of southeastern Massachusetts is a particularly important area for the endangered northwest Atlantic roseate tern because most of the population congregates in this area for several months during the post-breeding staging period prior to fall migration. USGS scientists are examining long-term temporal variation in staging site use and survival of terns prior to the construction of offshore wind turbines. These data could be useful for evaluating the timing of risks to roseate terns from proposed offshore wind energy projects.

Photograph by Karli Rogers, National Park Service.

Endangered northwest Atlantic roseate tern.



Offshore wind energy lease areas off the coasts of Rhode Island and Massachusetts (map by Bureau of Ocean Energy Management [OCS, Outer Continental Shelf]).

Contact

Jeffrey Spendelow, USGS Patuxent Wildlife Research Center, jspendelow@usgs.gov, (301) 497–5665

Publications

Spendelow, J.A., 2018, Roseate tern use of staging sites in the Northeastern United States, *in* Macleod-Nolan, C., comp., Annual Roseate Tern Newsletter 2017 (no. 11. April 2018): Bedfordshire, England, Roseate Tern LIFE Project, p. 59–65, http://roseatetern.org/news/annual-roseate-tern-newsletter-2017.

Spendelow, J.A., and Eichenwald, A.J., 2018, Post spring migration colony-site prospecting by roseate terns (*Sterna dougallii*): North American Bird Bander, v. 43, no. 1, p. 1–6, https://pubs.er.usgs.gov/publication/70198082.

Spendelow, J.A., and Eichenwald, A.J., 2018, Rapid departure of roseate terns (*Sterna dougallii*) following large-scale nest failure: Wilson Journal of Ornithology, v. 130, no. 2, p. 485–492, https://doi.org/10.1676/17-017.1.

Nichols, J.M., Spendelow, J.A., and Nichols, J.D., 2017, Using optimal transport theory to estimate transition probabilities in metapopulation dynamics: Ecological Modelling, v. 349, p. 311–319, https://doi.org/10.1016/j.ecolmodel.2017.06.003.

Spendelow, J.A., 2017, Rapid 3-week transition from migration to incubation in a female roseate tern (*Sterna dougallii*): North American Bird Bander, v. 42, no. 3, p. 62–64, https://pubs.er.usgs.gov/publication/70194706.

Spendelow, J.A., and Lugo, G., 2017, First evidence that paired roseate terns travel together during spring migration: North American Bird Bander, v. 42, no. 3, p. 60–62, https://pubs.er.usgs.gov/publication/70194705.

Althouse, M.A., Cohen, J.B., Spendelow, J.A., Karpanty, S.M., Davis, K.L., Parsons, K.C., and Luttazi, C.F., 2016, Quantifying the effects of research band resighting activities on staging terns in comparison to other disturbances: Waterbirds, v. 39, no. 4, p. 417–421, https://doi.org/10.1675/063.039.0412.

Nisbet, I.C.T., Monticelli, D., Spendelow, J.A., and Szczys, P., 2016, Pre-breeding survival of roseate terns *Sterna dougallii* varies with sex, hatching order and hatching date: Ibis, v. 158, no. 2, p. 327–334, https://doi.org/10.1111/ibi.12359.

36. Spatial and Foraging Ecology of Brown Pelicans in the South Atlantic Bight

Brown pelicans are a species of concern in many States and can serve as an indicator species for marine, coastal, and estuarine ecosystem health because they interact with all three ecosystems and across a range of trophic systems. There is potential overlap between pelican use areas and proposed or existing BOEM activities around development of offshore wind, oil, or gas. Information about the fine-scale habitat use of brown pelicans in the marine environment is needed to determine the probability of pelican exposure to offshore energy development activities. USGS scientists are attaching GPS tags to pelicans in South Carolina, Georgia, and northeast Florida to assess foraging ranges, movement patterns, and migration paths. This research also complements pelican tracking efforts being conducted in the GOM.

Contact

Patrick Jodice, USGS South Carolina Cooperative Fish and Wildlife Research Unit, pjodice@clemson.edu, (864) 656–6190

Photograph by Patrick Jodice, U.S. Geological Survey.

A tagged eastern brown pelican at Bird Key, South Carolina.

Additional Resources

Modeling of Atlantic Coast Seabird Distributions

Flanders, N.P., Gardner, B., Winiarski, K.J., Paton, P.W.C., Taber, A., and O'Connell, A.F., 2015, Key seabird areas in southern New England identified using a community occupancy model: Marine Ecology Progress Series, v. 533, p. 277–290, https://doi.org/10.3354/meps11316.

The Atlantic Offshore Seabird Dataset Catalog

Wimer, M., and Benson, A., 2016, USGS Patuxent Wildlife Research Center Seabirds Compendium, ver. 1.1: U.S. Geological Survey occurrence dataset, https://www1.usgs.gov/obis-usa/ipt/resource?r=usgs_pwrc_seabirdscompendium&v=1.1.

Pacific Ocean

37. Pacific Marine Bird and Mammal Research and Monitoring Programs

The USGS and partners have gathered information about marine bird and mammal research and monitoring programs into an online database to support environmental risk assessments for species and habitats sensitive to offshore energy activities in the southern California and Washington-Oregon Planning Areas and the Hawaiian Outer Continental Shelf (OCS) of BOEM. The database includes information from programs that assessed distribution, abundance, and biology of marine birds, such as seabirds, waterbirds, sea ducks, or shorebirds, and marine mammals, such as cetaceans, pinnipeds, or sea otters. Much of the information focuses on species protected under the Endangered Species or Marine Mammal Protection Acts. This database can be easily updated as new information becomes available.

Contact

Josh Adams, USGS Western Ecological Research Center, josh_adams@usgs.gov, (831) 460–7566

Photographs by D. Pereksta, used with permission.

Collage of at-sea images.

38. Southern California Marine Bird and Mammal Surveys

The Southern California Bight and the Pacific OCS biome off the central coast of California support a diverse assemblage of marine birds and mammals. This area supports substantial global populations of several species, including black storm-petrel, brown pelican, Scripps's murrelet, elegant tern, and approximately half of the world population of endemic ashy storm-petrels. USGS scientists are conducting aerial surveys and developing new techniques to provide updated status and distribution of seabirds and marine mammals in areas where renewable energy projects may be proposed and relate this updated information to past surveys.

Photograph by Jonathan Felis, U.S. Geological Survey.

A sooty shearwater takes off just offshore of Capitola, California.

Contact

Josh Adams, USGS Western Ecological Research Center, josh_adams@usgs.gov, (831) 460–7566

Publications

Kelsey, E.C., Felis, J.J., Czapanskiy, M., Pereksta, D.M., and Adams, J., in press, Collision and displacement vulnerability to offshore wind energy infrastructure among marine birds of the Pacific Outer Continental Shelf: Journal of Environmental Management.

Adams, J., Kelsey, E.C., Felis, J.J., and Pereksta, D.M., 2017, Collision and displacement vulnerability among marine birds of the California Current System associated with offshore wind energy infrastructure (ver. 1.1, July 2017): U.S. Geological Survey Open-File Report 2016–1154, 116 p., https://doi.org/10.3133/ofr20161154.

Takekawa, J.Y., Perry, W.M., Adams, J., Felis, J.J., Williams, L.L., Yee, J.L., Orthmeyer, D.L., Mason, J.W., McChesney, G.J., McIver, W.R., Carter, H.R., and Golightly, R.T., 2017, At-sea distribution and abundance of seabirds and marine mammals off southern California GIS resource database—Aerial seabird and marine mammal surveys off southern California, 1999–2002: U.S. Geological Survey data release, https://doi.org/10.5066/F7PK0D9P.

Adams, J., Felis, J.J., Mason, J.W., and Takekawa, J.Y., 2015, Pacific Continental Shelf Environmental Assessment (PaCSEA) GIS resource database—Aerial seabird and marine mammal surveys off northern California, Oregon, and Washington, 2011–2012: U.S. Geological Survey data release, https://doi.org/10.5066/F7668B7V.

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39. Predictive Modeling of Marine Bird Spatial Distributions on the Pacific Outer Continental Shelf

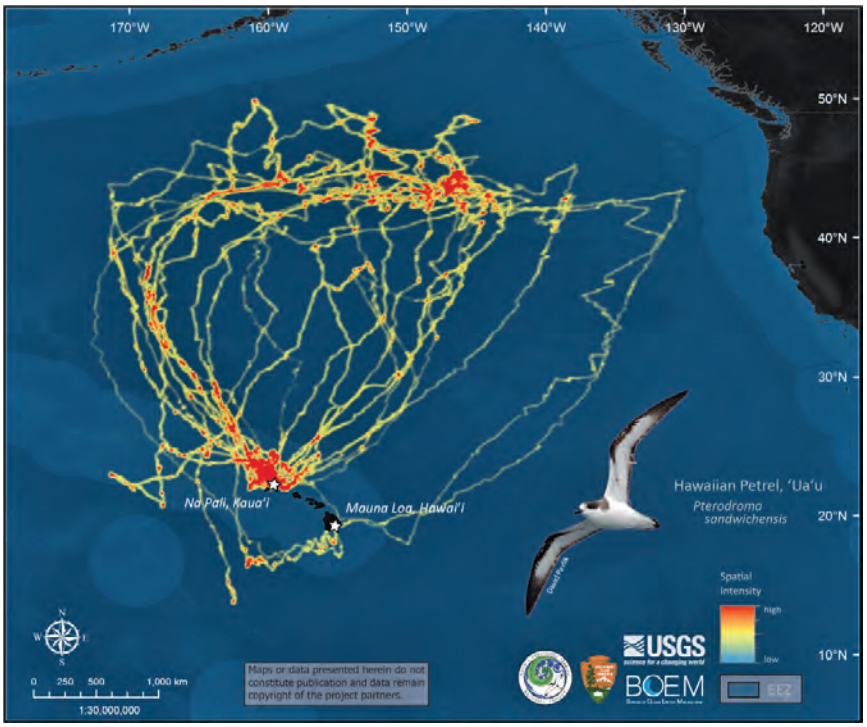
California, Oregon, and Washington are engaged with BOEM to plan the siting of offshore energy projects within the territorial sea and OCS regions. The USGS and collaborators are using historic, vessel-based, at-sea transect survey data coupled with oceanographic and environmental data to develop predictive models of marine bird distributions. These mapped data can be used to map hot and coldspot areas of relative bird occurrence and abundance throughout a large region of the California Current System, helping Pacific OCS States and BOEM prioritize areas for energy development.

Contact

Josh Adams, USGS Western Ecological Research Center, josh_adams@usgs.gov, (831) 460–7566

40. Main Hawaiian Islands Breeding Seabird Atlas

The main Hawaiian Islands (MHI) and associated offshore areas provide substantial breeding habitat for more than 19 seabird species. BOEM and the State of Hawai‘i have received proposals to develop offshore renewable energy-related projects within waters surrounding the main islands. These projects have the potential to negatively affect seabirds through interactions with wind-turbine structures, lighted facilities, elevated power lines on land, and lighted ships offshore. BOEM and other Federal, State, and local resource managers overseeing offshore renewable energy development within the waters surrounding the MHI require comprehensive, quantitative data of seabird colony locations, extents, and breeding population sizes to inform siting, conservation, and restoration actions for affected species. USGS and partners are working on a comprehensive atlas of MHI seabird colonies that can be used to generate predictions of at-sea distributions among seabirds on the basis of colony size and location, central-place foraging theory, and new empirical data from at-sea ranging studies throughout the MHI.



Hawaiian petrel at-sea movements from several breeding colonies in Hawai‘i (from USGS, https://www.werc.usgs.gov/ProjectSubWebPage.aspx?SubWebPageID=3&ProjectID=254).

Contact

Josh Adams, USGS Western Ecological Research Center, josh_adams@usgs.gov, (831) 460–7566

Gulf of Mexico

41. Distribution of Landbirds During Migratory Stopover in the Gulf of Mexico Region

Each spring and fall, millions of landbirds migrate through the GOM region and depend on stopover sites for food and cover. In areas along the northern and western Gulf, where development of liquefied natural gas export terminals is increasing, it is critical in conservation planning efforts to know where birds consistently stop to rest and forage. In support of the USFWS, the USGS is using weather surveillance radar from 2008 to 2015 to quantify the stopover distribution of landbirds during spring and fall migrations. The USFWS can use these data to inform environmental assessments of energy projects, such as liquefied natural gas export terminals, pipelines, and wind turbines, and other development, such as cellular towers and roads.

Contact

Wylie C. Barrow, Jr., USGS Wetland and Aquatic Research Center, barroww@usgs.gov, (337) 266–8668

42. Overland Migration of Marine Birds in a Wind Energy Corridor

The Pacific coast of the Isthmus of Tehuantepec in Mexico contains a substantial wetland complex supporting large aggregations of nonbreeding waterbirds. Extensive wind energy development has occurred in the plains bordering these wetlands. This study examined movement patterns of three marine-associated bird species in the northern GOM. Data provide evidence that marine birds from the Gulf region overwinter along the Pacific coast of Mexico and use the isthmus as a migratory corridor. This research can help resource managers better understand the various risks that marine birds may encounter during migration.

Contact

Patrick Jodice, USGS South Carolina Cooperative Fish and Wildlife Research Unit, pjodice@clemson.edu, (864) 656–6190

Publication

Lamb, J.S., Newstead, D.J., Koczur, L.M., Ballard, B.M., Green, M.C., and Jodice, P.G.R., 2018, A bridge between oceans—Overland migration of marine birds in a wind energy corridor: Journal of Avian Biology, v. 49, no. 2, e01474, p. 1–9, https://doi.org/10.1111/jav.01474.

43. Spatial and Reproductive Ecology of Brown Pelicans in the Gulf of Mexico

The GOM contains a high density of oil infrastructure and a rich assemblage of seabirds, yet baseline data on at-sea distribution and habitat use of these species are poorly understood. The brown pelican is a focal species for studies about risk exposure in the marine environment because of its distribution, behavior, and known sensitivity to chemical and oil contaminants. To assist the USFWS, BOEM, State agencies, and the Gulf of Mexico Avian Monitoring Network in developing management plans and future research and monitoring efforts, the USGS is studying colony-specific movement patterns, habitat use at sea, and reproduction for brown pelicans. Movement data collected using GPS satellite tags on 85 adult pelicans breeding in the region can help resource managers assess the spatial ecology of the brown pelican.

Contact

Patrick Jodice, USGS South Carolina Cooperative Fish and Wildlife Research Unit, pjodice@clemson.edu, (864) 656–6190

Publications

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Lamb, J.S., Satge Y.G., and Jodice, P.G.R., 2017, Diet composition and provisioning rates of nestlings determine reproductive success in a subtropical seabird: Marine Ecology Progress Series, v. 581, p. 149–164, https://doi.org/10.3354/meps12301.

Photograph by Juliet Lamb, U.S. Geological Survey.

Brown pelican at breeding colony, Raccoon Island, Louisiana.

Publications About Offshore Oil Spill Effects

Fallon, J.A., Smith, E.P., Schoch, N., Paruk, J.D., Adams, E.A., Evers, D.C., Jodice, P.G.R., Perkins, C., Schulte, S., and Hopkins, W.A., 2018, Hematological indices of injury to lightly oiled birds from the Deepwater Horizon oil spill: Environmental Toxicology and Chemistry, v. 37, no. 2, p. 451–461, https://doi.org/10.1002/etc.3983.

Haney, J.C., Jodice, P.G.R., Montevecchi, W.A., and Evers, D.C., 2017, Challenges to oil spill assessment for seabirds in the deep ocean: Archives of Environmental Contamination and Toxicology, v. 73, no. 1, p. 33–39, https://doi.org/10.1007/s00244-016-0355-8.

Grassland Birds and Waterbirds

Photograph from U.S. Fish and Wildlife Service.

A pair of whooping cranes.

Grassland Birds in the Northern Prairie and Great Plains

44. Prairie Grouse Lek Dynamics in Landscapes Near Wind Energy Facilities in North Dakota and South Dakota

The northern Great Plains has high potential for wind energy development, particularly along the Missouri Plateau in North and South Dakota. The area also provides important grassland breeding habitat for sharp-tailed grouse and greater prairie-chicken. Potential impacts of wind energy development on prairie grouse populations and trends at a landscape level have not been assessed in this region. From 2003 to 2014, the USGS conducted spring lek counts of prairie grouse in study areas with and without wind turbines as part of a larger study to assess the impacts of wind energy development on grassland birds. These data, with data collected by North Dakota Game and Fish Department and South Dakota Game, Fish, and Parks Department, are being used to assess the potential impacts of wind energy development on grouse lek counts and trends at a landscape level.

Contact

Wesley E. Newton, USGS Northern Prairie Wildlife Research Center, wnewton@usgs.gov, (701) 253–5523

45. Estimating Displacement Rates of Grassland Birds and Waterfowl From Wind Energy Development

Indirect impacts of wind energy development can include the displacement of some species of breeding grassland birds. USGS scientists have partnered with the USFWS to develop a method for quantifying displacement rates of grassland birds and waterfowls from wind energy development to provide an option for industry to mitigate for land-use changes associated with development. Using results from previous studies that established displacement behavior in several species of grassland birds and waterfowl (Loesch and others, 2013), USGS and USFWS scientists can estimate the amount of grasslands and wetlands needed to support displaced pairs of birds. This tool can be applied in situations where compensatory mitigation for impacted habitat is desirable or required.

Contact

Jill A. Shaffer, USGS Northern Prairie Wildlife Research Center, jshaffer@usgs.gov, (701) 253–5547

Publication

Shaffer, J.A., and Buhl, D.A., 2015, Effects of wind-energy facilities on breeding grassland bird distributions: Conservation Biology, v. 30, no. 1, p. 59–71, https://doi.org/10.1111/cobi.12569.

46. Tools for Identifying and Prioritizing Areas Used by Migrating Whooping Cranes

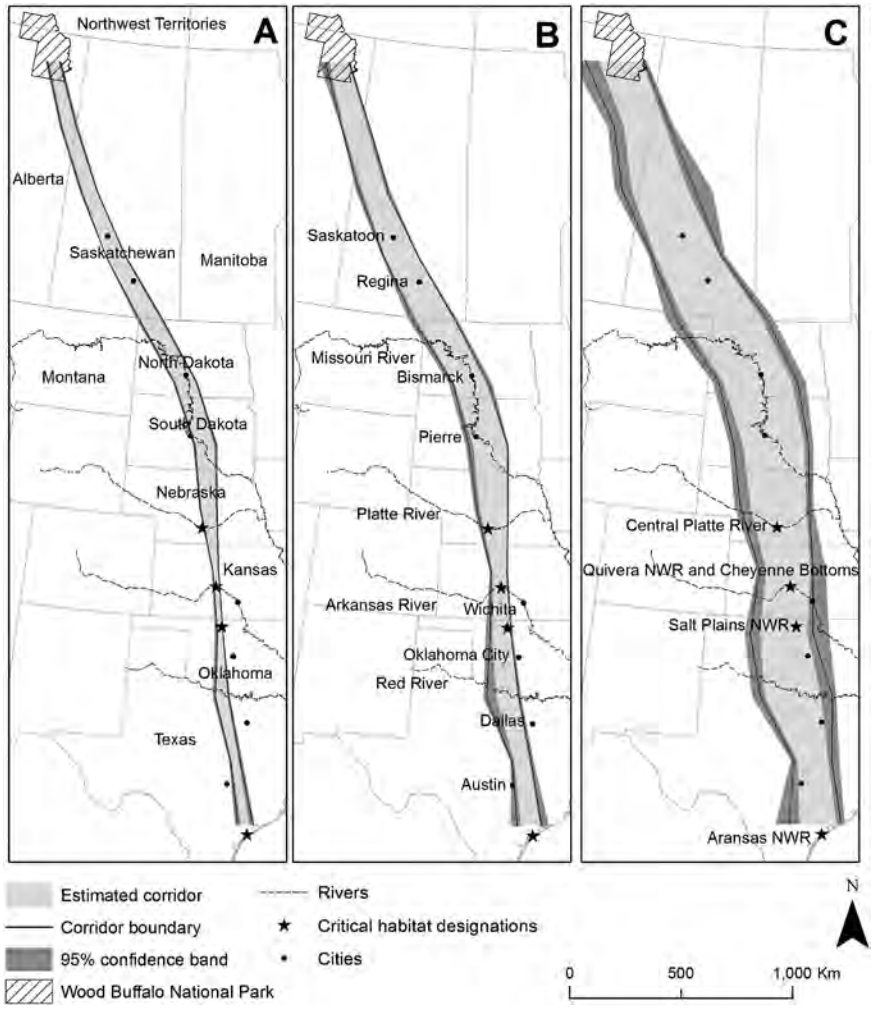
Whooping cranes of the Aransas-Wood Buffalo population migrate twice each year through the Great Plains between Canada and Texas. To assist with identifying migration areas across this endangered species' migration range and help with recovery efforts of this population of whooping cranes, the USGS and partners delineated a migration corridor that identifies areas used by most birds during their migrations. In partnership with USFWS, USGS scientists also created a tool that predicts wetland and other landscape features cranes would most likely use during future migrations. These tools offer the USFWS and partners ways to identify landscapes that may be of conservation importance to migrating whooping cranes.

Contact

Aaron Pearse, USGS Northern Prairie Wildlife Research Center, apearse@usgs.gov, (701) 253–5509

Publications

Niemuth, N.D., Ryba, A.J., Pearse, A.T., Kvas, S.M., Brandt, D.A., Wangler, B., Austin, J.E., and Carlisle, M.J., 2018, Opportunistically collected data reveal habitat selection by migrating whooping cranes in the U.S. Northern Plains: The Condor, Ornithological Applications, v. 120, no. 2, p. 343–356, https://doi.org/10.1650/CONDOR-17-80.1.



Migration corridors for whooping cranes of the Aransas-Wood Buffalo population, delineating (*A*) 50 percent core, (*B*) 75 percent core, and (*C*) 95 percent core migration areas, with 95 percent confidence bands (from Pearse and others, 2018, fig. 1).

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47. Population Dynamics of Piping Plovers and Least Terns in Response to Missouri River Management

The USGS is leading a multiagency regional study to understand population dynamics of piping plovers and least terns on the Missouri River. These federally listed species nest on riverine sandbars and reservoir shorelines of the Missouri River, and the availability and quality of their habitat change in response to climate and water-management activities. The U.S. Army Corps of Engineers (USACE) manages the Missouri River to benefit a wide variety of uses, including hydropower, recreation, water supply, navigation, flood control, and fish and wildlife. The USACE is planning to create suitable piping plover and least tern breeding habitat along the Missouri River as part of the Missouri River Recovery Program. The USGS-led study is providing population demographic and dispersal information that can inform decisions about management, conservation, and recovery of these species and overall management of the Missouri River.

Contact

Michael J. Anteau, USGS Northern Prairie Wildlife Research Center, manteau@usgs.gov, (701) 253–5507

Image from U.S. Geological Survey.

Collage of least tern and piping plover research on the Missouri River System.

Publications

Toy, D.L., Roche, E.A., and Dovichin, C.M., 2017, Small high-definition video cameras as a tool to resight uniquely marked interior least terns (*Sternula antillarum athalassos*): Waterbirds, v. 40, no. 2, p. 180–186, https://doi.org/10.1675/063.040.0211.

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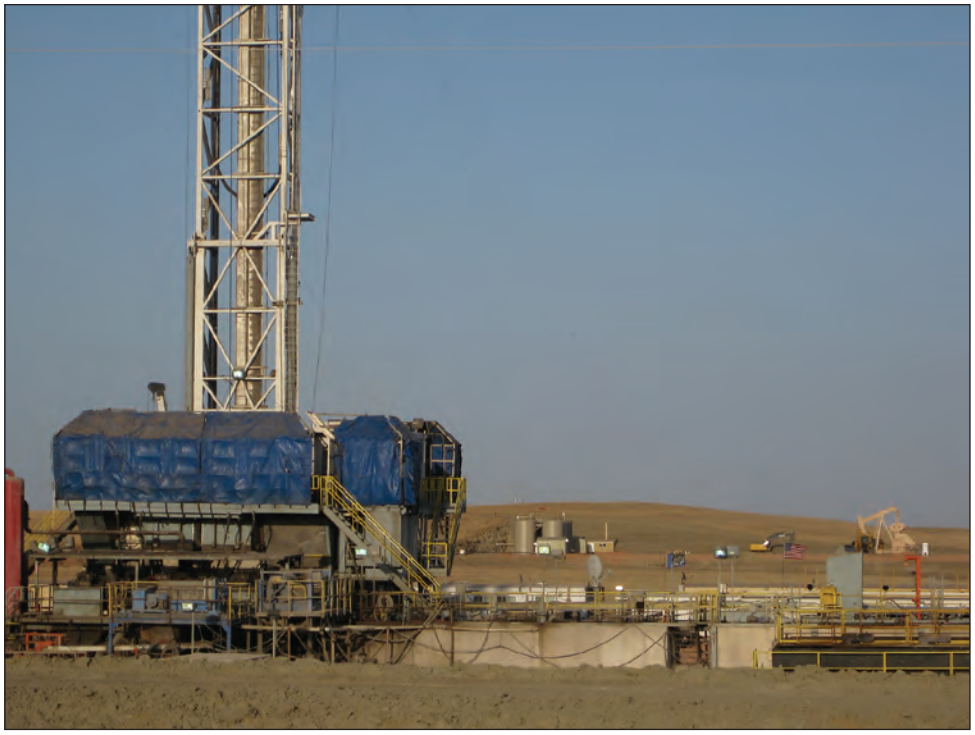
Roche, E.A., Dovichin, C.M., and Arnold, T.W., 2014, Field-readable alphanumeric flags are valuable markers for shorebirds—Use of double-marking to identify cases of misidentification: Journal of Field Ornithology, v. 85, no. 3, p. 329–338, https://doi.org/10.1111/jofo.12072.

48. Birds and the Bakken Formation: Oil Well, Land Cover, and Species Distribution Data

The USGS is leading a project to measure the effects of well development on birds in the Williston Basin in eastern Montana, western North Dakota, and South Dakota. Scientists plan to create maps that combine data on habitat conversion and species distribution to describe the effects of disturbance from oil well pads on biodiversity. Models are also being developed to display past and potential future effects of energy development on grassland birds. This information may assist managers with prioritizing areas for conservation in the Williston Basin.



Photograph by Stephanie Gaswirth, U.S. Geological Survey.

A drill rig in the Bakken oil field in Stark County, western North Dakota.

Contact

Todd Preston, USGS Northern Rocky Mountain Science Center, tmpreston@usgs.gov, (406) 994–5034

49. Lesser Prairie-Chicken Population and Habitat Ecology

The lesser prairie-chicken currently occupies a range that includes parts of Colorado, Kansas, New Mexico, Oklahoma, and Texas. This species has experienced population declines due to both direct and indirect habitat loss, including conversion of native rangeland to cropland and disturbance from energy development. The USGS developed a population viability analysis, or PVA model, to predict future population status of the lesser prairie-chicken in four ecoregions across the species' range. Studies by the USGS and collaborators predict habitat suitability for lesser prairie-chicken leks by exploring lesser prairie-chicken occurrence in relation to landscape characteristics, drought, and anthropogenic effects, such as distance to active wells, roads, highways, transmission lines, and tall structures. Habitat suitability models, combined with other landscape information, form the basis of a habitat assessment tool that can be used to guide siting of development projects and targeting of areas for conservation.

Contacts

Clint Boal, USGS Texas Cooperative Fish and Wildlife Research Unit, cboal@usgs.gov, (806) 742–2851
Dave Haukos, USGS Kansas Cooperative Fish and Wildlife Research Unit, dhaukos@ksu.edu, (785) 532–5761

Publications

Robinson, S.G., Haukos, D.A., Plumb, R.T., Lautenbach, J.M., Sullins, D.S., Kraft, J.D., Lautenbach, J.D., Hagen, C.A., and Pitman, J.C., 2018, Nonbreeding home-range size and survival of lesser prairie-chickens: Journal of Wildlife Management, v. 82, no. 2, p. 413–423, https://doi.org/10.1002/jwmg.21390.

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Jarnevich, C.S., Holcombe, T.R., Grisham, B.A., Timmer, J., Boal, C.W., Butler, M.J., Pitman, J., Kyle, S.C., Klute, D., Beauprez, G.M., Janus, A., and Van Pelt, W.E., 2016, Assessing range-wide habitat suitability for the lesser prairie-chicken: Avian Conservation and Ecology, v. 11, no. 1, 18 p., https://doi.org/10.5751/ace-00807-110102.

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Winder, V.L., Carrlson, K.M., Gregory, A.J., Hagen, C.A., Haukos, D.A., Kesler, D.C., Larsson, L.C., Matthews, T.W., McNew, L.B., Patten, M.A., Pitman, J.C., Powell, L.A., Smith, J.A., Thompson, T., Wolfe, D.H., and Sandercock, B.K., 2015, Factors affecting female space use in ten populations of prairie chickens: Ecosphere, v. 6, no. 9, p. 1–17, https://doi.org/10.1890/ES14-00536.1.

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Birds in the Intermountain West

Photograph by Matthew Lee, U.S. Geological Survey.

Greater sage-grouse.

50. Potential Impacts of Future Oil and Gas Development and Climate Change on Greater Sage-Grouse in Southwest Wyoming

Oil and gas development and climate change have the potential to affect sage-grouse, but little is known about the influences these changes may have on population trajectories. USGS scientists used spatially explicit and individual-based models to simulate sage-grouse responses to changing development infrastructure by using a range of expected development intensities and restrictions. Sage-grouse responses to climate-induced vegetation changes of future climate scenarios were also simulated to evaluate the influence of climate on sage-grouse abundance and distribution. Preliminary results underscore the need to spatially evaluate multiple causes of incremental change to plan landscapes that include human activities and wildlife.

Contacts

Cameron L. Aldridge, USGS Fort Collins Science Center, aldridgec@usgs.gov, (970) 226–9433
Julie A. Heinrichs, USGS Fort Collins Science Center, jheinrichs@usgs.gov, (970) 226–9149

51. Effects of Energy Development on Greater Sage-Grouse and Their Predators

An increasing human footprint across ecosystems in the American West often results in disturbance to native vegetation and related changes that are favorable to generalist predator species, such as ravens. A large portion of the Great Basin supports proposed and recently developed energy transmission lines and renewable energy sources, such as geothermal energy and wind. Further energy infrastructure development could continue to fragment the contiguous sagebrush-steppe ecosystems that provide seasonal habitat for greater sage-grouse populations. The USGS, in collaboration with other Federal and State agencies and private industry, is working to understand how energy development and habitat loss influence predator-prey interactions between ravens and nesting sage-grouse. This science can provide resource managers with information and tools to help develop guidelines for future energy-related projects that minimize adverse impacts on sage-grouse populations.

Contacts

Michael Casazza, USGS Western Ecological Research Center, mike_casazza@usgs.gov, (530) 669–5075
Peter Coates, USGS Western Ecological Research Center, pcoates@usgs.gov, (530) 669–5073

Publications

O'Neil, S.T., Coates, P.S., Brussee, B.E., Jackson, P.J., Howe, K.B., Moser, A.M., Foster, L.J., and Delehanty, D.J., 2018, Broad-scale occurrence of a subsidized avian predator—Reducing impacts of ravens on sage-grouse and other sensitive prey: Journal of Applied Ecology, July, early view, 33 p., https://doi.org/10.1111/1365-2664.13249.

Coates, P.S., Brussee, B.E., Ricca, M.A., Dudko, J.E., Prochazka, B.G., Espinosa, S.P., Casazza, M.L., and Delehanty, D.J., 2017, Greater sage-grouse (*Centrocercus urophasianus*) nesting and brood-rearing microhabitat in Nevada and California—Spatial variation in selection and survival patterns: U.S. Geological Survey Open-File Report 2017–1087, 79 p., https://doi.org/10.3133/ofr20171087.

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Coates, P.S., Howe, K.B., Casazza, M.L., and Delehanty, D.J., 2014, Landscape alterations influence habitat use of nesting buteos and ravens within sagebrush ecosystem—Implications for transmission line development: The Condor, v. 116, no. 3, p. 341–356, https://doi.org/10.1650/CONDOR-13-126.1.

52. Implications of Anthropogenic Activities on Greater Sage-Grouse Populations in Nevada

The USGS has initiated a study at nine sites across Nevada to answer questions related to short- and long-term effects on sage-grouse habitat selection, population vital rates, and movement patterns from disturbance caused by wind turbines, gold mining, geothermal energy production, hydraulic fracturing for oil, and transmission line development. This information can help managers develop guidelines that minimize the negative effects of these activities on greater sage-grouse and their associated habitat.

Contact

Peter Coates, USGS Western Ecological Research Center, pcoates@usgs.gov, (530) 669–5073

Additional Publications About Grassland Birds and Waterbirds

Greater Sage-Grouse

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Big Game and Other Terrestrial Mammals

Photograph by Samantha Dwinnell, U.S. Geological Survey.

Mule deer does and fawns gather on their winter range before beginning their spring migration north through the Wyoming Range mountains, Wyoming.

53. Migration Corridors for Big Game

As habitat loss and fragmentation increase across ungulate ranges, identifying and prioritizing migration routes for land-use planning and conservation has taken on a new urgency. Research attention is currently focused on determining whether continued energy development will lead to the loss of the foraging benefit of migration. USGS research in Wyoming has advanced our understanding of the importance of migration for large ungulates in the West, specifically quantifying how migrating animals track spring green-up during migration, a behavior termed "surfing the green wave." Research on corridors in which migrating animals interact with housing and energy development suggests that the resulting behavioral modifications can alter optimal foraging. In collaboration with Federal, State, and university partners, the USGS has developed the Migration Mapper (https://migrationinitiative.org/content/migration-mapper) software that provides a step-by-step analysis to map migration corridors from the underlying GPS locations. Resulting corridor maps can easily be made available for managers, policymakers, land trusts, sportsmen's groups, and other NGOs to use in conservation planning. A current effort is underway, through USGS-led regional workshops, to train wildlife managers from Western States to analyze migration data, and the USGS continues to develop tools and methods necessary to identify opportunities to enhance conservation and management of ungulate migration corridors.

Contact

Matthew Kauffman, USGS Wyoming Cooperative Fish and Wildlife Research Unit, mkauffm1@uwyo.edu, mkauffman@usgs.gov, (307) 766–5415

Publications

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54. Oil and Gas Development Influences on Big Game Hunting in Wyoming

To better understand how oil and gas development affects big game hunting, USGS scientists examined the influence of oil and gas development density on harvest efficiency within all hunting areas in Wyoming from 2008 to 2014 for three big-game species: elk, mule deer, and pronghorn. The presence of oil and gas wells had a positive influence on harvest efficiency for elk and mule deer. Although there was no overall effect to pronghorn, there was a negative influence of wells on juvenile pronghorn harvest efficiency. Changes in harvest efficiency due to expanding oil and gas development could alter the amount of time hunters spend hunting and their chances of harvesting an animal, which could have subsequent impacts on hunter satisfaction, game populations, and economic revenue generated by recreational hunters.

Contact

Jay Diffendorfer, USGS Geosciences and Environmental Change Science Center, jediffendorfer@usgs.gov, (303) 236–5369

Publication

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55. Pygmy Rabbit Distribution and Abundance Relative to Energy Development in Wyoming

Pygmy rabbits rely on sagebrush for both food and cover year-round and are sensitive to oil and gas development. Pygmy rabbits are a species of conservation concern in several States. In Wyoming, USGS scientists are investigating the influence of oil and gas development on pygmy rabbit populations. This research can help determine the distribution of pygmy rabbit habitat relative to ongoing oil and gas well development and how far from the nearest well pad, road, or pipelines pygmy rabbit presence and abundance may be affected. The scientists anticipate expanding this work to other States where pygmy rabbits and energy development co-occur. This information can help inform the development of future oil and gas fields and reduce the effects of disturbance on pygmy rabbits and other sagebrush obligate wildlife.

Contact

Stephen Germaine, USGS Fort Collins Science Center, germaines@usgs.gov, (970) 226–9107

Publications

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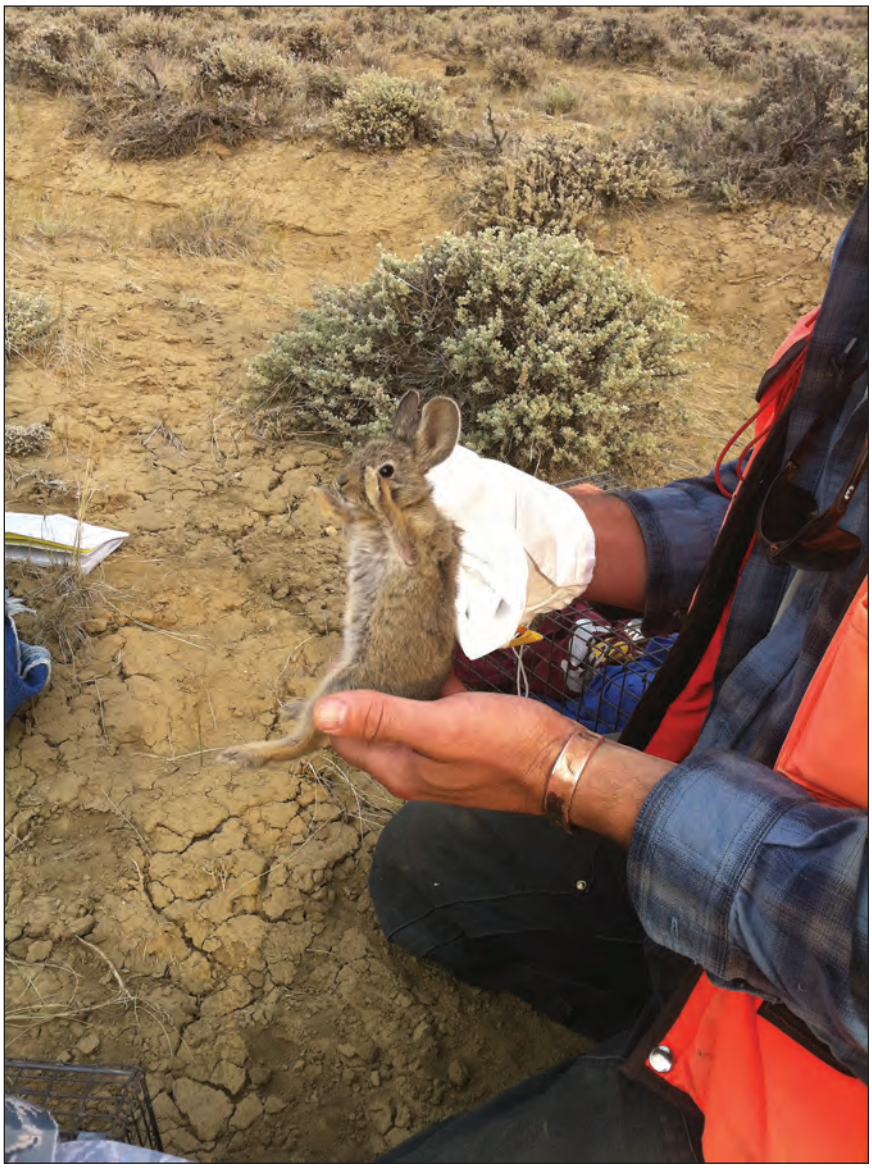
A pygmy rabbit sits in the dirt near its burrow.



USGS wildlife technician radio-tags a juvenile pygmy rabbit in Wyoming.

Photographs by Stephen Germaine, U.S. Geological Survey.

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Alaska Marine and Avian Species

Photograph by Ryan Askren, U.S. Geological Survey.

Greater white-fronted geese flying near Chipp South field camp area, North Slope, Alaska.

56. Summary of Wildlife-Related Research in the Coastal Plain of the Arctic National Wildlife Refuge

The USGS summarized publicly available information from studies within the 1002 Area of the Arctic National Wildlife Refuge as well as terrestrial and coastal ecosystems elsewhere in the Arctic Coastal Plain that are relevant to the 1002 Area. The report provides an update on earlier research summaries on caribou, forage quality and quantity, polar bears, muskoxen, and snow geese, and resources such as forage quality and quantity. The report also includes information on new research related to climate, migratory birds, permafrost, coastal erosion, coastal lagoons, fish, water resources, and the potential effects of industrial disturbance on wildlife.

A porcupine caribou herd on the coastal plain of the Arctic National Wildlife Refuge.

Contact

John M. Pearce, USGS Alaska Science Center, jpearce@usgs.gov, (907) 786–7094

Publication

Pearce, J.M., Flint, P.L., Atwood, T.C., Douglas, D.C., Adams, L.G., Johnson, H.E., Arthur, S.M., and Latty, C.J., 2018, Summary of wildlife-related research on the coastal plain of the Arctic National Wildlife Refuge, Alaska, 2002–17: U.S. Geological Survey Open-File Report 2018–1003, 27 p., https://doi.org/10.3133/ofr20181003.

57. Breeding Territory Retention in Pacific and Yellow-Billed Loons in the National Petroleum Reserve–Alaska

USGS scientists evaluated the role of breeding success and competition on territory retention by Pacific and yellow-billed loons. Annual territory retention rates were greater than 90 percent regardless of prior nesting success in a territory. Occupied territories were also frequently visited by nonbreeding loons. Yellow-billed loon results suggest there is limited habitat in the National Petroleum Reserve–Alaska (NPR–A) for new territories, and the extent of breeding habitat in northern Alaska may be limiting the size of the breeding population. In contrast, Pacific loons appear more able to establish new territories outside occupied territories. Study results indicate that territory retention and apparent survival rates for both loon species are high, and chick production does not affect loon territory retention. This information may be useful for guiding future oil and gas development near yellow-billed loon nesting areas.

Contact

John M. Pearce, USGS Alaska Science Center, jpearce@usgs.gov, (907) 786–7094

58. North Pacific Pelagic Seabird Survey Data

The USGS produced the North Pacific Pelagic Seabird Database (https://alaska.usgs.gov/science/biology/nppsd/index.php), an online resource compiling the results of 40 years of bird surveys from the United States, Canada, Japan, and Russia. The database documents the abundance and distribution of 160 seabird and 41 marine mammal species over a 26-million-square-kilometer, or 10-million-square-mile, region of the North Pacific. This database is a powerful tool for analysis and mitigation of anthropogenic effects on marine ecosystems of the Arctic and North Pacific, including the impacts of oil development and production, fisheries, and vessel traffic. Use of this tool also provides an unprecedented opportunity to study the biogeography and marine ecology of dozens of species of seabirds and marine mammals throughout their range in Continental Shelf waters of the United States.

Contacts

Gary S. Drew, USGS Alaska Science Center, gdrew@usgs.gov, (907) 786–7168

John Piatt, USGS Alaska Science Center, jpiatt@usgs.gov, (360) 774–0516

Publications

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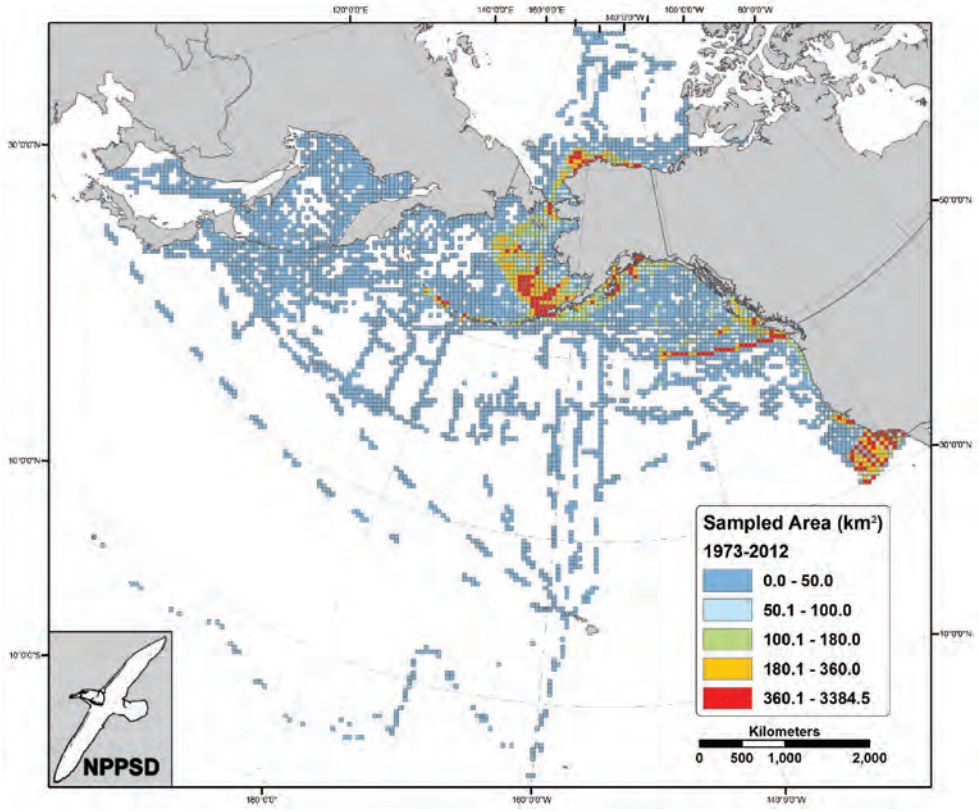

Distribution of samples (number of square kilometers surveyed) in the North Pacific Pelagic Seabird Database (NPPSD) version 2.0, 1973–2012. The area sampled within 50 × 50 kilometer cells was summed for all years (from Drew and others, 2015.)

59. Status of Seabirds and Forage Fish in Cook Inlet, Alaska

Seabird densities in lower Cook Inlet are among the highest in Alaska, and populations were decimated by the 1989 *Exxon Valdez* oil spill. Large resident and migratory seabird populations are sustained by local stocks of key forage fish species. Monitoring of seabird populations and forage fish stocks in potential oil and gas lease areas is a BOEM priority, both to mitigate the impacts of development and to assess the impact of potential oil spills. In 2016, the USGS initiated new studies to update knowledge gained from seabird and forage fish studies in lower Cook Inlet from 1995 to 2000, in advance of potential lease sales and associated activities in Cook Inlet during 2017 and beyond. These studies are also assessing change in seabird and fish populations following anomalous high temperatures in 2014–16.

Contact

John Piatt, USGS Alaska Science Center, jpiatt@usgs.gov, (360) 774–0516

60. Gulf Watch Alaska Program for Quantifying Coastal Marine Ecosystem Change

Oil and gas development and transportation activities are major components of Alaska's economy, and some of these activities occur along Alaska's coasts. The USGS is engaged in a collaborative marine monitoring program, Gulf Watch Alaska (https://gulfwatchalaska.org/), which documents the status, variation over time, and underlying drivers of change in Alaska's coastal marine ecosystems. This work quantifies the abundance, distribution, and change in hundreds of marine species, including many of high interest to management agencies. The USGS has been heavily involved in studies documenting the effects of the 1989 *Exxon Valdez* oil spill on the recovery of the wildlife population. This work provides a context for understanding the potential response of marine ecosystems to energy development relative to other sources of change.

Photograph by Sarah Schoen, U.S. Geological Survey.

Sea otter with pup in the Gulf of Alaska.

Contact

Grant V. Hilderbrand, USGS Alaska Science Center, ghilderbrand@usgs.gov, (907) 786–7076

Publications

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61. Quantifying the Response of Pacific Walrus to Ocean Noise in the Arctic

Walruses spend the majority of their time in water, where their underwater acoustic environment enables them to communicate with one another using sound and thus respond to disturbance. USGS scientists are using telemetry data and remote sensing information of sea ice and other environmental variables to study the effects of ocean noise from vessel traffic and offshore industrial activities on Pacific walrus activity patterns. Models are being developed to link levels of activity patterns to walrus energy expenditures and their potential effect on walrus rates of reproduction and survival. The results of these studies can be used to quantify the potential population-level impacts to walruses from offshore oil and gas development and associated support vessels off the coast of arctic Alaska.

Contact

Grant V. Hilderbrand, USGS Alaska Science Center, ghilderbrand@usgs.gov, (907) 786–7076

Publications

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62. Distribution and Abundance of Pacific Walrus in Relation to Offshore Development in Alaska

Increasing ice-free periods in the Arctic creates greater opportunities for offshore oil and gas development in the Chukchi Sea, Alaska. These activities, and their reliance on onshore infrastructure and shipping, require information on the distribution of Pacific walrus and their habitats to identify ways for industry to operate effectively while meeting conservation goals set by government agencies. USGS scientists developed novel satellite radio tracking devices to map feeding areas used by walruses. These maps are used by the U.S. Navy and the U.S. Coast Guard for managing vessel transit corridors. Scientists are now developing ways to use unmanned aircraft systems to estimate the abundance and distribution of Pacific walruses and their habitats in the Chukchi Sea. These studies have informed incidental take regulations and mitigation measures that can guide offshore development in minimizing interactions with walrus foraging and resting areas.

Photograph by Tyrone Donnelly, U.S. Geological Survey.

Pacific walrus resting on a piece of sea ice in the Chukchi Sea.

Contact

Grant V. Hilderbrand, USGS Alaska Science Center, ghilderbrand@usgs.gov, (907) 786–7076

Publications

Battaile, B.C., Jay, C.V., Udevitz, M.S., and Fischbach, A.S., 2017, Evaluation of a method using survey counts and tag data to estimate the number of Pacific walruses (*Odobenus rosmarus divergens*) using a coastal haulout in northwestern Alaska: Polar Biology, v. 40, no. 7, p. 1359–1369, https://doi.org/10.1007/s00300-016-2060-5.

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63. Measuring the Impacts of Industrial Activities on Polar Bears

USGS scientists are characterizing change in the abundance, distribution, and health of polar bears relative to human activities in the Arctic. These studies emphasize the identification of critical habitats potentially at risk of disturbance from industrial activities along Alaska's arctic coast. This work has informed efforts of U.S. Department of the Interior (DOI) agencies and industry when considering the consequences of oil spills and exposures to pollutants and actions to mitigate such occurrences. The USGS continues to work closely with DOI and industry partners to identify circumstances in which industrial activities likely adversely affect polar bears. Future work is expected to focus on the potential for resource development activities on land and offshore to directly and indirectly benefit polar bear behavior and health.

Photograph from U.S. Geological Survey.

Polar bear.

Contact

Grant V. Hilderbrand, USGS Alaska Science Center, ghilderbrand@usgs.gov, (907) 786–7076

Publications

Durner, G.M., and Atwood, T.C., 2018, A comparison of photograph-interpreted and IfSAR-derived maps of polar bear denning habitat for the 1002 area of the Arctic National Wildlife Refuge, Alaska: U.S. Geological Survey Open-File Report 2018–1083, 12 p., https://doi.org/10.3133/ofr20181083.

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Bowen, L., Miles, A.K., Waters, S., Meyerson, R., Rode, K., and Atwood, T., 2015, Gene transcription in polar bears (*Ursus maritimus*) from disparate populations: Polar Biology, v. 38, no. 9, p. 1413–1427, https://doi.org/10.1007/s00300-015-1705-0.

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64. Mitigating the Impacts of Energy Development on Polar Bears

The USGS works closely with other DOI agencies to identify science needed to inform actions that mitigate the impacts of energy development on polar bears. Information generated by USGS scientists is used by the USFWS to guide regulations regarding the incidental take of polar bears by industry, the BOEM to guide decisions regarding permitting of offshore oil and gas exploration and extraction, and the BLM to mitigate the effects of energy development on polar bears that den within the NPR–A. USGS work is focusing on improving decision-making tools for these agencies to assess the relative importance of environmental and anthropogenic stressors to polar bears.

Contact

Grant V. Hilderbrand, USGS Alaska Science Center, ghilderbrand@usgs.gov, (907) 786–7076

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Durner, G.M., and Atwood, T.C., 2018, A comparison of photograph-interpreted and IfSAR-derived maps of polar bear denning habitat for the 1002 area of the Arctic National Wildlife Refuge, Alaska: U.S. Geological Survey Open-File Report 2018–1083, 12 p., https://doi.org/10.3133/ofr20181083.

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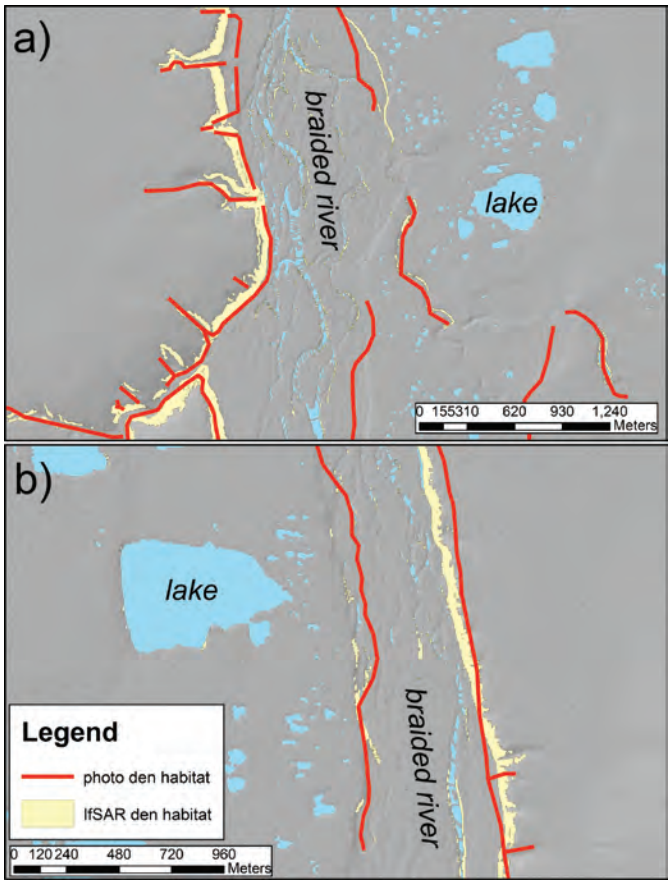


Comparisons of photograph-interpreted and interferometric synthetic aperture radar (IfSAR)-derived polar bear maternal denning habitat in the 1002 Area of the Arctic National Wildlife Refuge, Alaska. Photograph-interpreted habitat followed large and easily identified terrain features identified on aerial photographs. IfSAR-derived habitat identified landscape nuances including isolated pockets of suitable habitat. (Note delineated habitat on lakeshores and in braided rivers [from Durner and Atwood, 2018]).

Atwood, T.C., Marcot, B.G., Douglas, D.C., Amstrup, S.C., Rode, K.D., Durner, G.M., and Bromaghin, J.F., 2016, Forecasting the relative influence of environmental and anthropogenic stressors on polar bears: Ecosphere, v. 7, no. 6, e01370, https://doi.org/10.1002/ecs2.1370.

Durner, G.M., Simac, K., and Amstrup, S.C., 2013, Mapping polar bear maternal denning habitat in the National Petroleum Reserve—Alaska with an IfSAR digital terrain model: ARCTIC, v. 66, no. 2, p. 197–206, https://doi.org/10.14430/arctic4291.

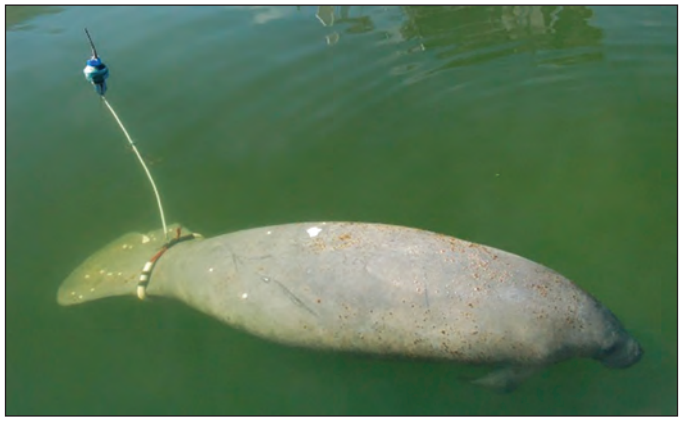
Marine Animals

Photograph by Robert Bonde, U.S. Geological Survey.

Florida manatee.

65. Florida Manatee Movement and Habitat Use in the Northern Gulf of Mexico

USGS scientists are investigating the distribution of Florida manatees and their habitats and travel corridors in the northern GOM. Health assessments were performed on manatees known to travel to the northern GOM, and GPS tracking devices that provide telemetry to acquire fine-scale habitat use and movement were attached to the mammals. Scientists are also conducting field studies to characterize local resources in areas that support manatee habitat or consistent use. This information is being used to inform the risk of interactions between manatees and vessels traveling to and from oil and gas structures.



Photograph by Kit Curtin, U.S. Geological Survey volunteer.

Florida manatee with GPS telemetry tracking device.

Contact

Daniel Slone, USGS Wetland and Aquatic Research Center, dslone@usgs.gov, (352) 264–3551

66. Science to Support the Transition of Florida Manatees to Natural Warm-Water Sites

A large segment of the Florida manatee population uses warm-water effluents of coastal powerplants as a winter refuge. The power industry in Florida is working with the USFWS and USGS in support of manatee research and protection measures as it upgrades powerplant operations and reduces warm-water effluents year-round. USGS scientists are developing models that estimate manatee survival and movement of individuals among warm-water sites. These models can be used by the USFWS and industry to inform implementation of the warm-water action plan.

Photograph by J. Reid, U.S. Geological Survey.

Florida Power and Light Cape Canaveral Energy Center in Brevard County, Florida. Interim warm water was provided for manatees during the 2010 reconstruction to convert from coal to gas.

Contacts

Catherine Langtimm, USGS Wetland and Aquatic Research Center, clangtimm@usgs.gov, (352) 264–3489

67. Gulf of Mexico Marine Assessment Program for Protected Species

The Gulf of Mexico Marine Assessment Program for Protected Species, or GoMMAPPS (https://www.boem.gov/gommapps/), is a multiagency partnership between the BOEM, USFWS, National Oceanic and Atmospheric Administration (NOAA), National Oceanographic Partnership Program (NOPP), and USGS with the goal of conducting broad-scale surveys of protected species to inform managers on the distribution and abundance of marine animals across seasons and years. The USGS is leading efforts to provide information to GoMMAPPS on abundance, distribution, and movement patterns of sea turtles and seabirds. Some of the largest gaps in knowledge of marine turtle and seabird ecology occur in areas of heavy oil and gas use, including BOEM's GOM Central and Western Planning Areas. Information generated by the USGS and its GoMMAPPS partners can be used in support of various BOEM/Bureau of Safety and Environmental Enforcement (BSEE) activities, including oil spill risk analysis, decommissioning of oil platforms, and movements of vessels.

Contacts

Kristen M. Hart (for sea turtles), USGS Wetland and Aquatic Research Center, kristen_hart@usgs.gov, (954) 377–5922
Margaret M. Lamont, USGS Wetland and Aquatic Research Center, mlamont@usgs.gov, (352) 209–4306
Patrick Jodice (for seabirds), USGS South Carolina Cooperative Fish and Wildlife Research Unit, pjodice@clemson.edu, (864) 656–6190

68. Sea Turtle Movements and Habitat Use in the Northern Gulf of Mexico

The USFWS and NOAA's National Marine Fisheries Service (NMFS) identified that information on the distribution, seasonal movements, vital rates, and habitat use for all life stages of marine turtles is needed to recover these threatened and endangered species. USGS scientists are attaching satellite tags and acceleration data loggers capable of logging dive data to provide fine-scale information on the dive profiles of Kemp's ridleys, loggerheads, and green sea turtles in the GOM. These dive profiles provide insight into turtle depth use, movement patterns, mortality risk, use of post-dredge sites, use of preferred thermal zones, and time spent near the vicinity of dredging activities. This study can directly address recovery and protection goals and provide information on in-water aggregations of sub-adult, juvenile, and adult marine turtles in the GOM.

Photograph by Andrew Crowder, U.S. Geological Survey.

Green sea turtle with satellite tag, Dry Tortugas National Park, Florida.

Contacts

Kristen M. Hart, USGS Wetland and Aquatic Research Center, kristen_hart@usgs.gov, (954) 377–5922
Margaret M. Lamont, USGS Wetland and Aquatic Research Center, mlamont@usgs.gov, (352) 209–4306

69. Deep-Sea Exploration to Advance Research on Coral/Canyon/Cold Seep Habitats

The OCS contains extensive and valuable commercial and recreational fisheries, as well as unique deep-sea communities, including corals and chemosynthetic seeps. BOEM, USGS, and NOAA's Office of Exploration and Research (OER) are partners on the Deep-Sea Exploration to Advance Research on Coral/Canyon/Cold Seep Habitats (DEEP SEARCH) study, which is part of the NOPP. DEEP SEARCH aims to further the understanding of the distribution of sensitive deep-sea habitats in the U.S. Atlantic region. As part of the Diversity, Systematics and Connectivity of Vulnerable Reef Ecosystems, or DISCOVRE project (https://www2.usgs.gov/ecosystems/environments/DISCOVRE/index.html), USGS scientists worked with BOEM managers to develop a multidisciplinary research program that focuses on ecosystem-based studies in areas considered for oil and gas leasing and (or) renewable energy development. The information generated from this project can allow managers to design and support an adaptive, ecosystem-based approach to DOI's stewardship responsibilities while allowing for development of offshore energy resources.

Photograph from Bureau of Ocean Energy Management, U.S. Geological Survey, and National Oceanic and Atmospheric Administration.

The submersible Alvin is used to observe and collect samples to depths reaching 4,500 meters.

Contact

Amanda Demopoulos, USGS Wetland and Aquatic Research Center, ademopoulos@usgs.gov, (352) 264–3490

Publications

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70. Changes to Infaunal Communities Associated With Deep-Sea Coral and Their Potential Recovery From the Deepwater Horizon Oil Spill

The Deepwater Horizon (DWH) oil spill effected changes in multiple ecosystems within the GOM, including coastal and deep-sea ecosystems that support large and valuable commercial and recreational fisheries and numerous threatened or endangered species. A few studies have documented the acute impacts of the spill to deep-sea communities, but long-term changes and recovery of communities have not been assessed. The USGS is leading an unprecedented 7-year post-spill assessment of the GOM-OCS deep-sea coral communities that tracks change in coral-associated sediment communities. These results can help inform future deep-sea ecosystem monitoring and restoration activities and can lead to the development of effective adaptive management and conservation strategies for these vulnerable ecosystems.

Contact

Amanda Demopoulos, USGS Wetland and Aquatic Research Center, ademopoulos@usgs.gov, (352) 264–3490

A comparison of normal coral with dead skeletal material covered by typical secondary colonization (right) and a wilting, dying coral covered with oil plume debris (left). Image courtesy of Lophelia II 2010, National Oceanic and Atmospheric Administration and Bureau of Ocean Energy Management.

A red bubblegum coral (*Paragorgia arborea*) and several colonies of *Primnoa* occupy a boulder in close proximity to an anemone and sea star in Norfolk Canyon. Image courtesy of National Oceanic and Atmospheric Administration.

Publications

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Additional Publications About Marine Mammals

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Langtimm, C.A., Kendall, W.L., Beck, C.A., Kochman, H.I., Teague, A.L., Meigs-Friend, G., and Peñaloza, C.L., 2016, Model description and evaluation of the mark-recapture survival model used to parameterize the 2012 status and threats analysis for the Florida manatee (*Trichechus manatus latirostris*): U.S. Geological Survey Open-File Report 2016–1163, 20 p., https://doi.org/10.3133/ofr20161163.

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Reptiles and Amphibians

Photographs by Patrick Kleeman, U.S. Geological Survey.

Western toads from Hot Creek, Nevada.

71. Distribution and Habitat Associations of Narrowly Endemic Great Basin Toads

Several species and subspecies of toads (*Anaxyrus* spp.) in the Great Basin are endemic to small spring systems, but the ecology of these toads is poorly understood. Entire ranges of these species, including the recently described Dixie Valley toad, are often in areas suitable for geothermal and other energy development. In 2018, the USGS, in collaboration with BLM, USFWS, Department of Defense, and the Nevada Department of Wildlife, initiated a research and monitoring program designed to better understand the ecology of narrowly endemic toads in the Great Basin. This research can be used to inform land-use and conservation planning efforts for these distinctive toads.

Contact

Brian Halstead, USGS Western Ecological Research Center, bhalstead@usgs.gov, (530) 669–5076

72. Desert Tortoise Translocations and Habitat Restoration

Renewable energy projects in southern California are frequently sited in desert tortoise habitat, creating the need to translocate tortoises to new areas. USGS scientists are studying desert tortoise habitat, disease prevalence, and shelter choices in support of wildlife and land-management decisions regarding site selection for tortoise translocations.

Publications

Mack, J.S., Schneider, H.E., and Berry, K.H., 2018, Crowding affects health, growth, and behavior in headstart pens for Agassiz's desert tortoise: Chelonian Conservation and Biology, v. 17, no. 1, p. 14–26, https://doi.org/10.2744/CCB-1248.1.

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Additional Publications About Reptiles and Amphibians

Desert Tortoise

Agha, M., Smith, A.L., Lovich, J.E., Delaney, D., Ennen, J.R., Briggs, J., Fleckenstein, L.J., Tennant, L.A., Puffer, S.R., Walde, A., Arundel, T.R., Price, S.J., and Todd, B.D., 2017, Mammalian mesocarnivore visitation at tortoise burrows in a wind farm: Journal of Wildlife Management, v. 81, no. 6, p. 1117–1124, https://doi.org/10.1002/jwmg.21262.

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Lovich, J.E., and Ennen, J.R., 2016, Energy development, *in* Jones, L.L.C., Halama, K.J., and Lovich, R.E., eds., Habitat management guidelines for amphibians and reptiles of the Southwestern United States: Birmingham, Ala., Partners in Amphibian and Reptile Conservation, Technical Publication HMG–5, 193 p.

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Lovich, J.E., Agha, M., Yackulic, C.B., Meyer-Wilkins, K., Bjurlin, C., Ennen, J.R., Arundel, T.R., and Austin, M., 2014, Nest site characteristics, nesting movements, and lack of long-term nest site fidelity in Agassiz's desert tortoises at a wind energy facility in southern California: California Fish and Game, v. 100, no. 3, p. 404–416, https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=93571&inline.

Amphibians

Hossack, B.R., Puglis, H.J., Battaglin, W.A., Anderson, C.W., Honeycutt, R.K., and Smalling, K.L., 2017, Widespread legacy brine contamination from oil production reduces survival of chorus frog larvae: Environmental Pollution, v. 231, pt. 1, p. 742–751, https://doi.org/10.1016/j.envpol.2017.08.070.

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Sweeten, S.E., and Ford, W.M., 2016, Validation of a stream and riparian habitat assessment protocol using stream salamanders in the southwest Virginia coalfields: Journal of American Society of Mining and Reclamation, v. 5, no. 1, p. 45–66, https://doi.org/10.21000/jasmr16010045.

Pollinators

Photograph from U.S. Geological Survey.

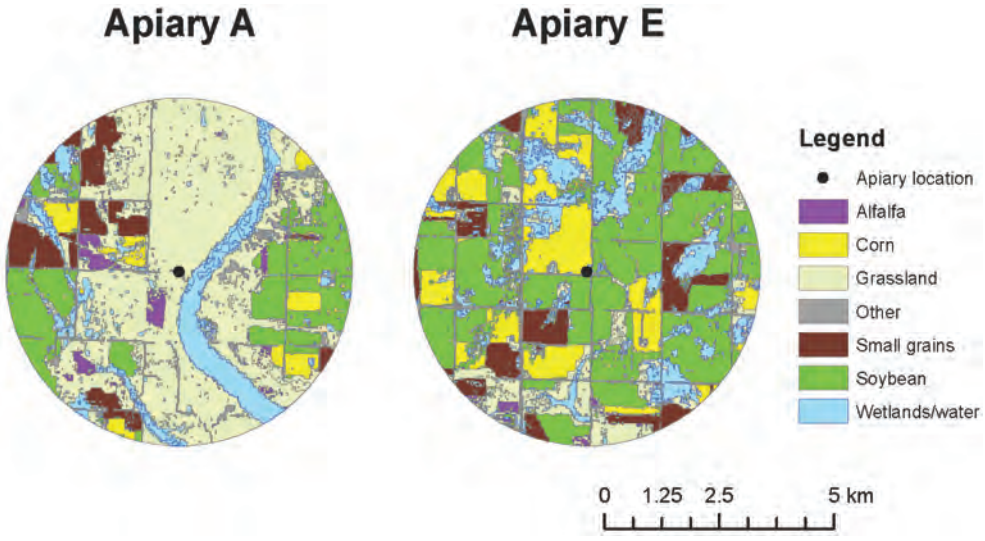
Meadow fritillary butterfly on swamp milkweed in the northern Great Plains.

73. Impact of Biofuel Crop Production on Pollinators in the Northern Great Plains

The USGS, in cooperation with the U.S. Department of Agriculture (USDA), is quantifying how recent reductions in USDA conservation program enrollments affect pollinator habitat. Scientists are also developing a risk assessment model to identify what portions of the northern Great Plains have undergone the most substantial land-use changes due to biofuel crop development while also supporting the highest density of commercial beekeepers. This study addresses several of the key information needs to better understand, minimize, and recover from pollinator losses.

Contact

Clint Otto, USGS Northern Prairie Wildlife Research Center, cotto@usgs.gov, (701) 253–5563



Land-use conditions surrounding apiaries in the Prairie Pothole Region (PPR) of North Dakota can vary substantially. Land use was quantified within a 4-kilometer radius around each apiary site in 2014 (from Smart and others, 2018).

Photograph by Clint Otto, U.S. Geological Survey.

Colony monitoring devices can be used to track and assess the health status of honey bees. Each colony was fitted with both a pollen trap (pink, above bottom board) and scale (below bottom board).

Publications

Otto, C.R.V., Zheng, H., Gallant, A.L., Iovanna, R., Carlson, B.L., Smart, M.D., and Hyberg, S., 2018, Past role and future outlook of the Conservation Reserve Program for supporting honey bees in the Great Plains: Proceedings of the National Academy of Sciences, v. 115, no. 29, p. 7629–7634, https://doi.org/10.1073/pnas.1800057115.

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74. Taxonomic Characterization of Bee Pollen Foraging

USGS scientists recently developed a genetic sequencing technique to identify pollen collected by foraging bees. The scientists are now using this technique to understand how land-use change and biofuel crop development affect forage for pollinators in agroecosystems by modeling historic forage patterns based on pollen collected from museum specimens of the federally endangered rusty patched bumble bee. This information can be used to evaluate specific plants that can be included in conservation and restoration programs for pollinators.

Contact

Clint Otto, USGS Northern Prairie Wildlife Research Center, cotto@usgs.gov, (701) 253–5563

Publications

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75. Designing Conservation Seeding Mixes

USGS scientists are working with the USDA to quantify the benefits of USDA conservation lands for supporting healthy pollinator populations in the northern Great Plains. One tool that can assist USDA managers is the USGS developed Pollinator Library (https://www.npwrc.usgs.gov/pollinator/). This library is a repository of insect visitation and environmental and land-use information that can assist land managers with conservation seeding mix designs for land enhancement programs. This tool may be useful for restoring habitat for pollinators in areas where marginally productive lands are retired from biofuel crop production.

Contact

Clint Otto, USGS Northern Prairie Wildlife Research Center, cotto@usgs.gov, (701) 253–5563

Publications

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Fish and Other Aquatic Species

Fish ladder at McNary Dam on the Columbia River, Washington and Oregon.

Fish Passage and Behavior at Hydropower Dams

76. Full-Scale Development and Evaluations of Fish Passage Structures and Fish Behavior

Many migratory fish species have been in decline worldwide due in large part to dams and poorly designed fishways that prevent fish from reaching spawning and feeding grounds. The USGS has a unique large-scale flume facility that allows for full-scale testing of upstream and downstream passage conditions with live test species. The S.O. Conte Anadromous Fish Research Center laboratory provides semicontrolled conditions that enable USGS, NMFS, DOE, and State scientists and engineers to improve and develop new fish passage designs and technologies and also identify behaviors and hydraulics that inform design criteria for successful fish passage. The goal of this work is to restore self-sustaining populations of migratory fish while maintaining a balance between energy production, water management, and ecosystem restoration.

Contacts

Theodore R. Castro-Santos, USGS Leetown Science Center, tcastrosantos@usgs.gov, (413) 863–3838
Alex Haro, USGS Leetown Science Center, aharo@usgs.gov, (413) 863–3806

Publications

Mulligan, K.B., Towler, B., Haro, A., and Ahlfeld, D.P., 2018, Downstream fish passage guide walls—A hydraulic scale model analysis: Ecological Engineering, v. 115, p. 122–138, https://doi.org/10.1016/j.ecoleng.2018.02.006.

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77. Innovative Fishway Entrance to Enhance Fish Passage

The USGS, in collaboration with the University of Massachusetts, was awarded an Innovative Solutions for Fish Passage at Hydropower Dams grant by the DOE in 2018 to develop and test a new fishway attraction and entrance technology designed to enhance fish passage. Relative to other technical fishway components, the Fishway Entrance Palisade is likely to have broad applicability to many target species including Atlantic salmon, American shad, alewife, and blueback herring. This work can benefit the hydropower industry by reducing fishway operation and maintenance costs, and can benefit restoration efforts for these species by providing more efficient and safe passage around riverine and other barriers.

Contact

Kevin B. Mulligan, USGS Leetown Science Center, kmulligan@usgs.gov, (413) 863–3837

78. Biotelemetry Studies of Fish Behavior and Passage Through Dams

Understanding and quantifying fish behavior is essential for identifying fish passage problems and developing effective passage solutions across hydropower dams and other manmade barriers. Biotelemetry, or using radio and acoustic telemetry to track biological organisms, has emerged as the method of choice for acquiring detailed, individual-based data to quantify passage and critical fish behaviors. Working in collaboration with the USFWS, NMFS, DOE, and State agencies, the USGS S.O. Conte Anadromous Fish Research Center scientists have adapted and developed advanced telemetry technologies for fish passage studies and statistical analysis methods for fish passage evaluations. These advances can help maximize the return on labor- and cost-intensive studies that integrate fish behavior with hydraulic and physical characteristics of passage structures to improve passage design.

Contacts

Theodore R. Castro-Santos, USGS Leetown Science Center, tcastrosantos@usgs.gov, (413) 863–3838
Alex Haro, USGS Leetown Science Center, aharo@usgs.gov, (413) 863–3806

Publications

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79. Understanding Downstream Fish Passage in the Willamette River Basin

Efforts are currently underway to improve fish passage conditions at dams in the Willamette Valley, Oregon, and enhance populations of anadromous fish species. The USGS, in cooperation with the USACE—who owns and operates the 13 Willamette Project dams, completed a synthesis of existing literature on downstream fish passage research in the Willamette River Basin. Threatened populations of Upper Willamette River Chinook salmon and steelhead reside within the boundaries of the Willamette Project and are a primary focus for regional resource managers. This synthesis can serve as an important reference for resource managers and others interested in downstream fish passage within the Willamette Project.

Photograph from the U.S. Geological Survey.

A fish passage project on Lookout Point Dam on the Willamette River in Lane County, Oregon.

Contacts

Toby J. Kock, USGS Western Fisheries Research Center, tkock@usgs.gov, (509) 538–2915
Amy C. Hansen, USGS Western Fisheries Research Center, ahansen@usgs.gov, (509) 538–2911

Publication

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80. Use of Acoustic Cameras to Study Behavior of Fish Routed Around a Hydroelectric Dam

USGS scientists used acoustic cameras to assess the behavior and abundance of bull trout-size fish at the entrance to the North Fork Reservoir juvenile fish floating surface collector (FSC). The purpose of the FSC is to collect downriver migrating juvenile salmonids at the North Fork Dam and safely route them around the hydroelectric dam. The acoustic cameras also determined if the presence of bull trout-size fish influenced the collection or abundance of juvenile salmonids near the FSC. Results from this study can be used by managers to help inform decisions about collection and passage solutions for juvenile salmonids at the FSC, as well as to identify the potential for predation by bull trout near the FSC entrance.

Contact

Noah Adams, USGS Western Fisheries Research Center, nadams@usgs.gov, (509) 538–2964

Publication

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81. Downstream Fish Passage and Survival Through Dams

Dams can negatively affect emigrating juvenile salmon populations because fish must pass through the impounded river created by the dam, negotiate a passage route at the dam, and emigrate through a riverine reach that has been affected by altered river discharge. USGS scientists in Washington State monitored the movements of radio-tagged juvenile salmonids released upstream from hydroelectric dams to study how fish move across reservoirs and passage structures to better understand how these structures and water discharge methods affect fish passage success and survival. Results from these studies can inform hydropower dam operators and resource managers on ways to improve route-specific salmon passage and survival.

Contact

Russell Perry, USGS Western Fisheries Research Center, rperry@usgs.gov, (509) 538–2942
Tobias J. Kock, USGS Western Fisheries Research Center, tkock@usgs.gov, (509) 538–2915

Publications

Kock, T.J., Evans, S.D., Hansen, A.C., Perry, R.W., Hansel, H.C., Haner, P.V., and Tomka, R.G., 2018, Evaluation of sockeye salmon after passage through an innovative upstream fish-passage system at Cle Elum Dam, Washington, 2017: U.S. Geological Survey Open-File Report 2018–1116, 30 p., https://doi.org/10.3133/ofr20181116.

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82. Developing Selective Fish Passage to Block Invasive Sea Lamprey

The sea lamprey is an invasive, parasitic fish species in the Great Lakes, causing damage to recreational and commercial fisheries, which are valued at more than $7 billion annually (Great Lakes Fishery Commission, 2018). USGS scientists, in collaboration with the Great Lakes Fisheries Commission, University of Massachusetts, Michigan State University, and the University of Guelph in Ontario, Canada, are evaluating velocity-based barriers, nonstick surfaces, and other strategies that take advantage of the relatively poor swimming abilities of lamprey. The goal is to develop selective fish passage that would block the passage of sea lamprey while allowing desirable fish species to pass through unharmed.

Photograph by Mona Khalil, U.S. Geological Survey.

Selective fish passage surfaces are tested in a flow device at the S.O. Conte Anadromous Fish Research Center to block sea lamprey movement across fish passageways.

Contact

Theodore R. Castro-Santos, USGS Leetown Science Center, tcastrosantos@usgs.gov, (413) 863–3838

Publications

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Hydropower Effects on Fish and Aquatic Resources

83. Hydropower Effects on River Food Webs

Aquatic insects are a cornerstone of river food webs. USGS scientists demonstrated that flow regimes on the Colorado River favoring hydroelectric-power generation can eliminate many aquatic insect species from downstream habitats. This research informed experimental flow releases from Glen Canyon Dam that are being conducted from May to August 2018. The experiment involves releasing stable and low flows every weekend, with hydropower-peaking flows occurring during weekdays. These "bug flows" are designed to minimally affect hydropower revenue while providing ideal egg laying conditions for aquatic insects on weekends.

Photograph courtesy of Dave Herasimtschuk, Freshwaters Illustrated.

Participants in a Grand Canyon Youth river trip deploy light traps along the banks of the Colorado River in the Grand Canyon (from Kennedy and others, 2016).

Contact

Theodore Kennedy, USGS Southwest Biological Science Center, tkennedy@usgs.gov, (928) 556–7374

Publications

Sabo, J.L., Caron, M., Doucett, R., Dibble, K.L., Ruhi, A., Marks, J.C., Hungate, B.A., and Kennedy, T.A., 2018, Pulsed flows, tributary inputs and food-web structure in a highly regulated river: Journal of Applied Ecology, v. 55, no. 4, p. 1884–1895, https://doi.org/10.1111/1365-2664.13109.

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84. Effects of Dam Operations on Endangered Fishes

Glen Canyon Dam operations affect downstream environmental conditions of the Colorado River in Glen and Grand Canyons which, in turn, affect resident aquatic species like fish. USGS scientists assessed the effects of temperature, turbidity, food availability, flow variability, and nonnative fish abundance on endangered humpback chub. Growth models showed that environmental conditions like temperature and duration of turbidity best described growth in sub-adult humpback chub. A model using data from tagged fish measured the effects of rainbow trout, an economically important nonnative sport fish, on humpback chub. Model results showed that rainbow trout have a negative effect on humpback chub survival and, to a lesser degree, their growth. Understanding the relative importance of various environmental factors on humpback chub allows managers to make informed decisions regarding the operation of Glen Canyon Dam and management actions intended to facilitate the recovery of this endangered species.

Photograph from U.S. Geological Survey.

Humpback chub.

Contact

Charles Yackulic, USGS Southwest Biological Science Center, cyackulic@usgs.gov, (928) 556–7379

Publication

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Photograph by Scott VanderKooi, U.S. Geological Survey.

Looking down on the Colorado River in Grand Canyon.

Photograph by Morgan Ford, U.S. Geological Survey.

Rainbow trout caught in Lees Ferry, Arizona (part of the trout fishery downstream from Glen Canyon Dam).

Additional Publications

Dzul, M.C., Yackulic, C.B., Korman, J., Yard, M.D., and Muehlbauer, J.D., 2017, Incorporating temporal heterogeneity in environmental conditions into a somatic growth model: Canadian Journal of Fisheries and Aquatic Sciences, v. 74, no. 3, p. 316–326, https://doi.org/10.1139/cjfas-2016-0056.

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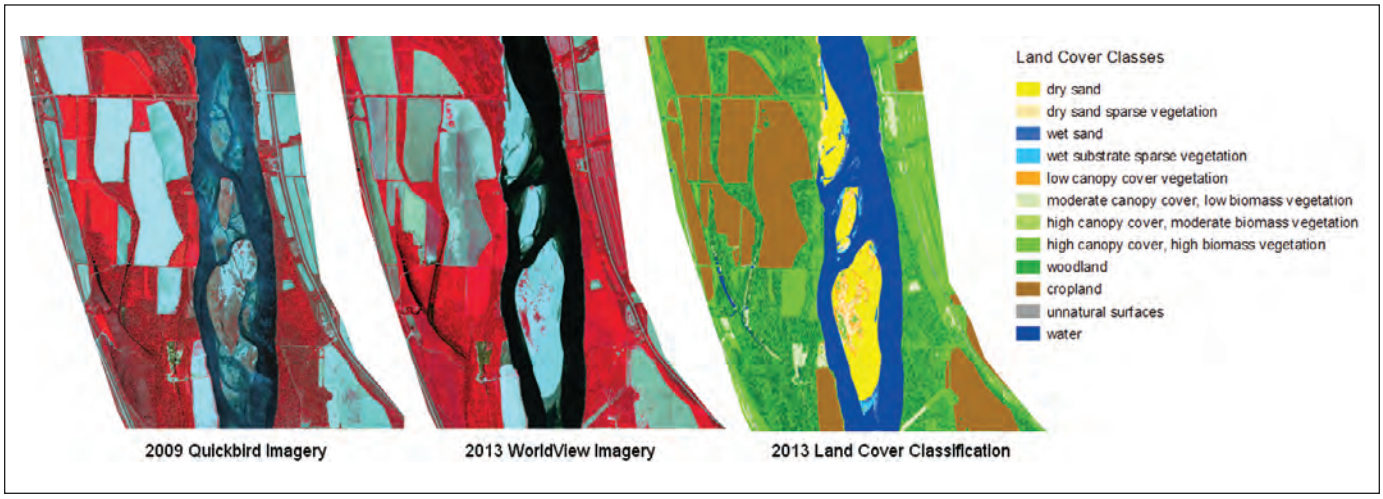
Optimizing Dam Operations and Management

85. Missouri River Emergent Sandbar Habitat Classification

Emergent sandbars on the Missouri River are breeding habitat for the endangered interior population of least terns and the threatened northern Great Plains population of piping plovers. The USACE operates several large dams on the river and manages water discharge from these dams for multiple purposes, including hydroelectric energy production and suitable habitat for threatened and endangered species. USGS scientists are using satellite imagery and remote-sensing methods to create maps for use in classifying and quantifying emergent sandbar habitat and study habitat dynamics in response to fluctuating water levels. These maps are used by the USACE to monitor and manage bare and sparsely vegetated sandbars, critical breeding habitat for these two species. These maps have been incorporated into USACE management plans and are planned to be released annually to the public beginning in 2019. The methods used to create these maps and a database of potential habitats are planned for publication.

Contact

Mark T. Wiltermuth, USGS Northern Prairie Wildlife Research Center, mwiltermuth@usgs.gov, (701) 253–5567



High spatial resolution satellite imagery and land-cover classification of a section of the Missouri River 34 kilometers north of Bismarck, North Dakota. Images show emergent sandbar conditions prior to and after a large flood event during 2011.

86. Improving Stream Temperature With Modification to Hydropower Dam Operation

The USACE owns and operates more than 10 dams in the Willamette watershed. The Willamette Basin biological opinion, issued by the NMFS (National Marine Fisheries Service, 2008), requires the USACE to assess the feasibility of developing project-specific alternatives for achieving fish passage as well as improved long-term temperature control downstream from these dams. USGS scientists are using models to simulate the effects of structural and operational scenarios and the effects downstream. USACE managers and engineers can use this information to determine the ways in which structural and (or) operational changes to dams can improve downstream water temperature and flow conditions for endangered fish species.

Photograph by U.S. Army Corps of Engineers.

Dam operators for the Detroit Dam on the North Santiam River in Oregon use temperature sensors for direct operational feedback, altering dam operations to create a more-natural seasonal temperature pattern downstream for fish.

Contact

Stewart Rounds, USGS Oregon Water Science Center, sarounds@usgs.gov, (503) 251–3280

Publications

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87. Guide for Monitoring Stream Temperature

Monitoring stream temperatures can help researchers and resource managers quantify the influence of water temperature on terrestrial and aquatic ecosystems. Although many stream temperature monitoring protocols exist, most are written for aquatic specialists. USGS and National Park Service scientists provided precise and easy-to-understand stream temperature monitoring protocols for nonspecialists. The protocols include instructions for using a specific brand of data loggers (Onset), including launching, checking factory calibration prior to field use, installing in streams for year-round monitoring, and inputting project data into databases.

Contact

Jason B. Dunham, USGS Forest and Rangeland Ecosystem Science Center, jdunham@usgs.gov, (541) 750–0990

Publication

Heck, M.P., Schultz, L.D., Hockman-Wert, D., Dinger, E.C., and Dunham, J.B., 2018, Monitoring stream temperatures—A guide for non-specialists: U.S. Geological Survey Techniques and Methods, book 3, chap. A25, 76 p., https://doi.org/10.3133/tm3A25.

88. Monitoring Total Dissolved Gas in Hydropower Dams Spills

Spill water from dams contains supersaturated dissolved gases, a condition created by the turbulent flow conditions attributed to the dam. High dissolved gas concentrations increase mortality to fish below dams. The USGS, in cooperation with the USACE, monitors total dissolved gas at USACE-owned dams in the Columbia and Willamette River systems in Oregon. The data from the study are used in real time by USACE dam operators to ensure total dissolved gas levels in spills meet U.S. Environmental Protection Agency (EPA) criteria.

Contact

Nora Herrera, USGS Oregon Water Science Center, nherrera@usgs.gov, (503) 251–3209

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89. Maintenance of Instream Flows and Water Temperatures for Salmon Egg Incubation

The USGS, in cooperation with the Alaska Energy Authority (AEA), measures and analyzes streamflow, water temperature, and intragravel water temperature downstream from the Bradley Lake dam. A minimum discharge of 1.13 cubic meters per second, or 40 cubic feet per second, in the lower river is required to protect salmon egg incubation habitat during the winter. This minimum flow requirement is based on an open-water instream flow study that did not consider the effects of ice formation, which is fatal to eggs. Data are being collected to determine if below-freezing temperatures occur at depths 25 to 30 centimeters, or 10 to 12 inches, below the streambed. These data can be used to determine if the minimum instream flow is sufficient to maintain above-freezing temperature in the streambed and allow for salmon egg incubation.

Contact

Jeff Conaway, USGS Alaska Science Center, jconaway@usgs.gov, (907) 786–7041

90. Aquatic Invasive Species Control Efforts and Dam Operations

Nonnative fishes, some potentially invasive, have been introduced in impoundments throughout the United States to create recreational fishing opportunities. The passage of individual fish and other aquatic organisms through dams as part of hydropower operations can lead to invasions of unwanted species. USGS scientists are developing and testing the feasibility of methods such as the use of liquid ammonia, carbon dioxide, and sound to eradicate undesirable species upstream and downstream from dams. The use of carbon dioxide has shown promise as a deterrent strategy for invasive fish species and could be an effective pest management tool to control invasive crayfish. Results from laboratory trials suggest red swamp and rusty crayfish avoid water enriched with carbon dioxide. The technology will be field tested in Michigan in partnership with the Michigan Department of Natural Resources to eradicate invasive crayfish from small ponds. Current efforts also focus on several fish and mollusks, including four species of nonnative Asian carp, round goby, and Dreissenid mussels (quagga mussels and zebra mussels).

Contact

Mark Gaikowski, USGS Upper Midwest Environmental Sciences Center, mgaikowski@usgs.gov, (608) 781–6221
David Ward, USGS Southwest Biological Science Center, dlward@usgs.gov, (928) 556–7280

Publications

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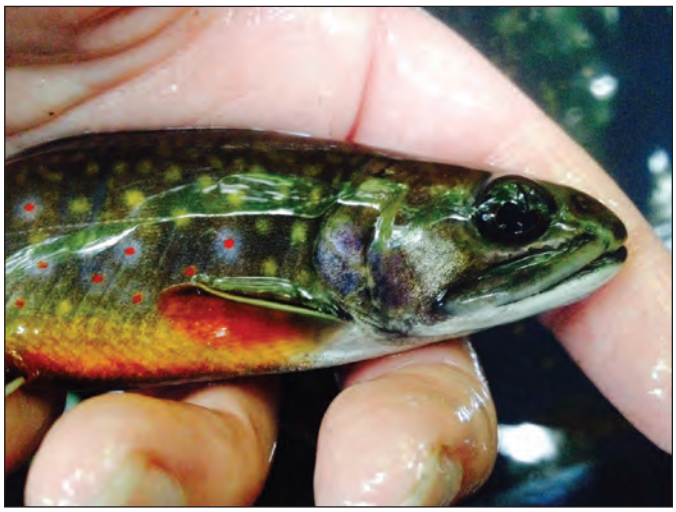
Oil and Gas Effects on Water Quality

91. Vulnerability of Brook Trout Streams to Shale Gas Development in the Upper Susquehanna River Basin

The Upper Susquehanna River Basin drains parts of Pennsylvania and New York, and includes many high-quality and native brook trout streams. USGS and West Virginia University scientists are using spatial modeling approaches to assess the potential cumulative effects of unconventional oil and gas (UOG) development on high-quality brook trout streams in the Pennsylvania portion of the basin, which has experienced relatively recent, rapid increase in UOG development. Vulnerability models were developed that incorporate all stages of the UOG development process—infrastructure, drilling, spills, and water withdrawals—that may affect fish and other aquatic resources. These models incorporate measures of aquatic health and status to identify streams that are vulnerable to UOG development. This vulnerability framework can be applied to a variety of ecosystems or energy development scenarios.



Photograph by Jeffrey Cole, U.S. Geological Survey.

Brook trout collected from a stream in Tioga County, Pennsylvania.

Contact

Kelly O. Maloney, USGS Leetown Science Center, kmaloney@usgs.gov, (304) 724–4579

Publications

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92. Toxicity Associated With Produced Waters From Oil and Gas Activity

The USGS and partners are investigating the potential effects of UOG activity on aquatic resources to assess toxicity levels and impacts on biological organisms. USGS scientists are measuring the levels of inorganic and organic compounds in streams following spills or downstream from wastewater facilities and studying shifts in microbial function, which can alter ecosystem processes, such as nutrient cycling, and can alter the resiliency of a community to perturbation. These studies can help identify changes in the microbial community in an environment affected by UOG wastewaters. Results can provide insight into the effects of oil brines on aquatic resources in an important rearing area for migratory waterfowl.

Contacts

Isabelle M. Cozzarelli, USGS National Research Program, icozzare@usgs.gov, (703) 648–5899
Aïda Farag, USGS Columbia Environmental Research Center, aida_farag@usgs.gov, (307) 733–2314
Denise M. Akob, USGS National Research Program, dakob@usgs.gov, (703) 648–5819

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eDNA for Species Detection and Conservation

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Atlantic sturgeon.

93. Using Genomics to Better Understand Habitat Use of the Atlantic Sturgeon

BOEM managers use information on the ecology of the federally protected Atlantic sturgeon in coastal waters to understand the potential impacts from offshore energy development and fulfill obligations required under Federal laws. USGS scientists are developing genomics tools aimed at providing a cost-effective, high-resolution way to characterize the sturgeon population structure and demographics. Scientists have assembled and annotated the complete mitochondrial genome of both the Atlantic and Gulf sturgeon, allowing for detection of Atlantic and Gulf sturgeon eDNA in water. These techniques can allow large numbers of sturgeon to be identified to their river and distinct population segment of origin, and facilitate accurate assessments of Atlantic sturgeon populations. These approaches are widely applicable to stock and impact assessments for a wide variety of imperiled or other species of management concern.

Contacts

Stephen Faulkner, USGS Leetown Science Center, faulkners@usgs.gov, (304) 724–4471
David Kazyak, USGS Leetown Science Center, dkazyak@usgs.gov, (304) 724–4577

Publications

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94. Estimating Fish Abundance Using eDNA

Environmental DNA (eDNA) quantitative analysis is being explored as a tool for monitoring the distribution and abundance of species; however, questions remain whether species' populations can be detected using this method. USGS scientists and partners evaluated different sampling methods and whether eDNA could be used to accurately predict the presence and abundance of several aquatic species, such as brook trout populations in remote streams in upstate New York and sockeye salmon in a small stream in Alaska. Study findings show that eDNA surveys can enable researchers to effectively characterize the presence as well as the abundance of certain species of fish in streams. The studies provide new insights into the use of quantitative applications of eDNA in conservation and stream management.

Contacts

Jeff Duda, USGS Western Fisheries Research Center, jduda@usgs.gov, (206) 526–2532
Barry P. Baldigo, USGS New York Water Science Center, bbaldigo@usgs.gov, (518) 285–5605

Publications

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95. A Model for Estimating Aquatic Species Density From eDNA

Environmental DNA (eDNA) analytical methods are effective for estimating site occupancy and species distribution of aquatic organisms. The next frontier of eDNA applications is to estimate species abundance and density. Building upon previous studies correlating eDNA concentration and associated animal density, researchers developed a modeling approach that uses eDNA and associated animal density data from a subset of sites to estimate animal density at other sites where only eDNA data are available. Areas were noted where the model could be further developed to yield more accurate estimates. This approach advances the difficult, but important, topic of inferring animal density from eDNA data.

Contact

David S. Pilliod, USGS Forest and Rangeland Ecosystem Science Center, dpilliod@usgs.gov, (208) 426–5202

Publication

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Wildlife Habitats and Ecosystem Functions

Photograph by Alan Cressler, used with permission.

Sugar Run, Susquehanna County, Pennsylvania.

96. Assessment of Forest Canopy Removal Due to Oil and Gas Development

USGS researchers assessed the volume of forest canopy removal in parts of Pennsylvania and New York to better understand the nature, extent, and magnitude of landscape change. Fine-scale lidar forest canopy geometric models were created to assess the volumetric change attributed to forest clearing from oil and gas development, clear cut forest harvesting, and urban and suburban development. Oil and gas infrastructure development removed a large volume of forest canopy from 2006 to 2013, and this removal spread over a large portion of the study area. Although timber operations, such as clear cutting, on Pennsylvania State Forest lands removed a larger total volume of forest during the same period, the removal was concentrated in a smaller area. Results of this study can help resource managers consider volumetric impacts of oil and gas development on ecosystems and place potential impacts in context with other ongoing land conversions.

Contact

John A. Young, USGS Leetown Science Center, jyoung@usgs.gov, (304) 724–4469

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97. Shale Gas Development in the Appalachians

Since 2005, the Marcellus Shale Formation in the Appalachian Basin has experienced exponential shale gas development, and development is projected to increase. USGS researchers and university collaborators have completed a series of studies to evaluate wildlife response to shale gas development that can help Federal and State land managers minimize effects on wildlife. The studies focused on the long-term response of an avian community in West Virginia to forest loss and fragmentation from shale gas development and the demography of Louisiana waterthrush and their benthic macroinvertebrate. Despite relatively small sitewide forest loss, waterthrush site quality and nest success declined as shale gas development increased. Results from these studies can inform best management practices for gas development.

Photograph by Jeffrey Spendelow, U.S. Geological Survey.

Louisiana waterthrush

Contact

Petra Wood, USGS West Virginia Cooperative Fish and Wildlife Research Unit, pbwood@wvu.edu, (304) 293–5090

Publications

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98. Terrestrial Impacts of Mountaintop Mining

Ecological research on mountaintop mining has been focused on aquatic impacts because the overburden, or mountaintop, is disposed of in nearby valleys, leading to a wide range of water-quality impacts on streams. Numerous impacts on the terrestrial environment from mountaintop mining also have been largely overlooked, even though they are no less wide ranging, severe, and multifaceted. USGS scientists are reviewing the impacts of mountaintop mining on the terrestrial environment in studies that complement existing research focused on impacts to aquatic environments. These studies can assist managers and regulators in evaluating the full impacts of mountaintop mining on the terrestrial environment.

Contact

Petra Wood, USGS West Virginia Cooperative Fish and Wildlife Research Unit, pbwood@wvu.edu, (304) 293–5090

Publications

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99. Aeolian Dust Associated With Oil and Gas Infrastructure in Sagebrush Ecosystems

The rapid expansion of energy development on Federal lands in southwestern Wyoming began in the early 2000s. Partners with the Wyoming Landscape Conservation Initiative expressed the need to better understand whether dust generated from energy development could be affecting wildlife and their habitats. USGS is conducting a long-term study of road dust and soil movement associated with a large energy development in south-central Wyoming. USGS scientists deployed dust samplers and collected vegetation samples to estimate dust flux and soil movement across a gradient of development to evaluate dust generation and distribution patterns. This study can be used by resource managers in Wyoming and elsewhere in the sagebrush steppe region to inform potential strategies to mitigate impacts attributed to dust.

Contacts

Pat Anderson, USGS Fort Collins Science Center, andersonpj@usgs.gov, (970) 226–9488
Daniel Manier, USGS Fort Collins Science Center, manierd@usgs.gov, (970) 226–9466
Timothy Assal, USGS Fort Collins Science Center, assalt@usgs.gov, (970) 226–9134

Photograph from U.S. Geological Survey.

Generation of road dust in the Continental Divide-Creston energy field, Wyoming

100. Land-Cover Changes in the Williston and Piceance Basins

The Williston Basin in the northern Great Plains and the Piceance Basin in western Colorado have experienced rapid energy development since 2000. USGS scientists evaluated land-cover changes from recent development along with changes in operational practices. This information can be used to model land-use requirements for future development. Evolving industry practices and proactive siting decisions, such as development along energy corridors and placing pads in areas previously altered by human activity, have the potential to reduce the ecological effects of future energy development.

Contact

Todd Preston, USGS Northern Rocky Mountain Science Center, tmpreston@usgs.gov, (406) 994–5034

Publications

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101. Effects of Energy Development on Environmental Resources of the Williston Basin

Energy development within the Williston Basin, especially development focused on the Bakken Formation, has led to unprecedented natural, social, and cultural change across the northern Great Plains. This development is expected to continue for at least the next 50 years as energy companies and scientists continue to discover new mineral-producing horizons and innovative technologies for extraction. The USGS developed a report in concert with the Bakken Federal Executive Group to review and synthesize the existing information about air, water, and wildlife resources that may be relevant in understanding the potential effects of oil and gas development in the Williston Basin.

Contact

Scott E. Morlock, USGS Midwest Region, smorlock@usgs.gov, (317) 600–2753

Publications

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102. Ecological Effects of Brine Contamination in the Prairie Pothole Region

Energy production in the Williston Basin results in the co-production of highly saline water, or brine. USGS researchers examined the effects of contamination from production waters derived from oil and gas development on macroinvertebrate communities. Scientists sampled 155 wetlands across a contamination gradient in the Prairie Pothole Region (PPR) and collected samples to determine macroinvertebrate taxonomic richness, wetland salinity, and chloride levels. Across this gradient, contaminated wetlands had lower invertebrate richness, diversity, and evenness; however, predictable, systematic shifts in invertebrate community structure were not detected.

Contact

Todd Preston, USGS Northern Rocky Mountain Science Center, tmpreston@usgs.gov, (406) 994–5034

Publications

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Photographs by Rachel Harrington, U.S. Geological Survey.

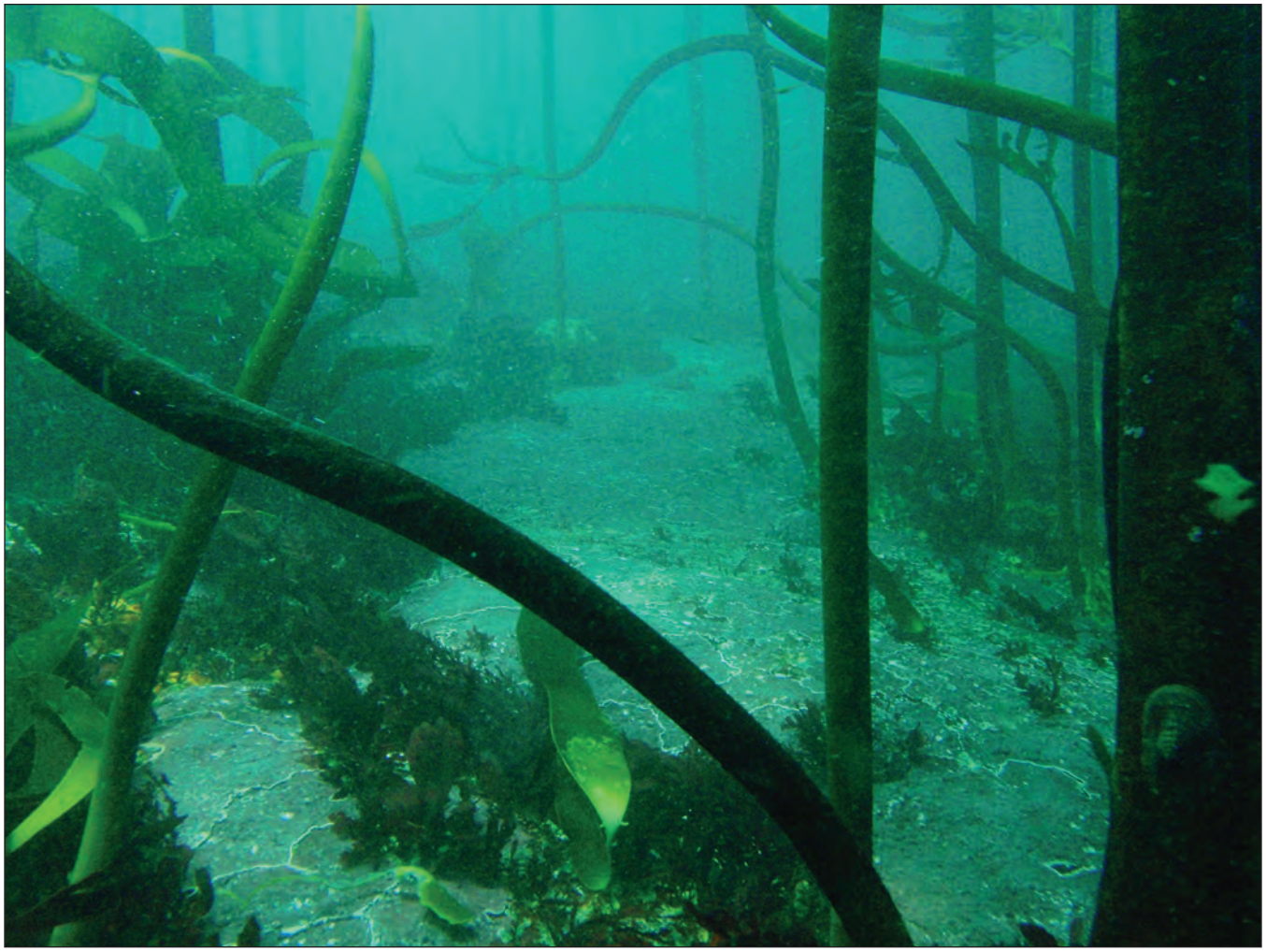
Insect traps in a wetland in North Dakota's Prairie Pothole Region.

103. Predicting the Effects of Wave Energy Facilities on Nearshore Ecosystems

The USGS is investigating the possible effects of wave energy conversion (WEC) devices on nearshore ecosystems, such as kelp forests. WEC devices pull potential energy from the rise and fall or surge of open ocean swells and convert it into energy for human use. WEC devices can affect the local environment through noise, hazard, construction, anchoring, animal entanglement, turbulence, sedimentation, fouling, and reduction in wave height. Results from these studies can help BOEM determine the degree to which WECs affect currents and other physical features of the marine environment and predict the ecological consequences of various siting options for proposed marine renewable energy facilities. These studies are being conducted in anticipation of an increase in the coming years of applications to BOEM for development of WEC devices on the Pacific OCS.

Contact

Kevin Lafferty, USGS Western Ecological Research Center, klafferty@usgs.gov, (805) 893–8778



Photograph by Peter Southwood, Wikimedia Commons, Creative Commons 3.0 license.

Kelp forest.

Conservation and Energy Development Planning Tools

Photograph from U.S. Department of Energy.

Utility-scale solar array on Moapa Band of Paiutes Indian land, Nevada.

104. Informing Energy Development Siting Decisions With Vertebrate Biodiversity Measures

USGS researchers developed vertebrate biodiversity metrics using existing data on suitable habitat for wildlife. The scientists used watershed-scale range models for vertebrate species developed through the USGS National Gap Analysis Program to illustrate how biodiversity metrics may be incorporated into renewable energy siting decisions. These metrics can inform siting guidance for energy development on public lands and help managers in identifying potential energy development conflicts with species of conservation concern.

Contact

Kathryn A. Thomas, USGS Southwest Biological Science Center, kathryn_a_thomas@usgs.gov, (520) 668–8299

Publication

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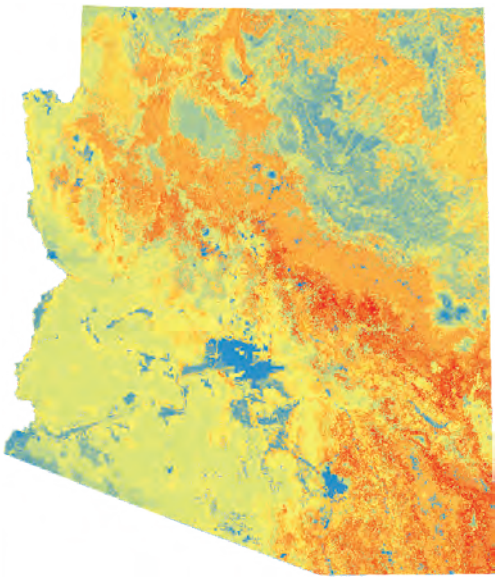


Image by Kathryn Thomas, U.S. Geological Survey.

Bat species richness in Arizona. The areas with the highest number of species (23 species) are shown in red, and the colors range down to the lowest number of species in blue.

105. Smart Energy Development in the Sagebrush Ecosystem

The USGS is at the forefront of developing science and tools to help inform policy and management decisions about various aspects of the energy development life cycle. These development strategies are particularly important in the American West where ongoing demands for limited natural resources in sagebrush ecosystems and the need to be cost-effective require that management and regulatory decisions be made at the broader landscape scale. Working with Federal, State, and industry partners, USGS scientists are developing natural resource information, management tools, risk assessments, and scenario planning that will form the scientific foundation needed to target areas in sagebrush ecosystems of high resource potential and low environmental concern to inform effective development strategies.

Photograph by Anna Wilson, U.S. Geological Survey.

Sagebrush lands in southwestern Wyoming.

Contact

Steven Hanser, USGS Ecosystems Mission Area, shanser@usgs.gov, (703) 648–4054

106. Quantifying the Potential Effects of Energy Development on Wildlife and Ecosystem Services

Energy resources are critical for a prosperous and secure Nation, and a clear understanding of the potential effects of energy resource development is necessary for efficient and minimally impactful energy extraction and production activities. USGS scientists are developing and applying probabilistic models to evaluate the potential effects of energy development on landscapes, wildlife, and ecosystem services, building from the geology-based USGS assessments of undiscovered petroleum resources. Ongoing projects are using the energySim model (https://energy.usgs.gov/OilGas/AssessmentsData/NationalOilGasAssessment/energySimAnRPackage.aspx) to understand potential surface disturbance changes in sediment erosion associated with energy development and the energy footprint model (https://www.sciencebase.gov/catalog/item/589e441ae4b099f50d3a0e6b) to evaluate the effects of sage-grouse core area policy on landscape patterns and wildlife habitat.

Contacts

Monica Dorning, USGS Geosciences and Environmental Change Science Center, mdorning@usgs.gov, (352) 264–3499
Jay Diffendorfer, USGS Geosciences and Environmental Change Science Center, jediffendorfer@usgs.gov, (303) 236–5369

Publications

Garman, S.L., 2018, A simulation framework for assessing physical and wildlife impacts of oil and gas development scenarios in southwestern Wyoming: Environmental Modeling and Assessment, v. 23, no. 1, p. 39–56, https://doi.org/10.1007/s10666-017-9559-1.

Martinez, C., 2017, energySim—An R package: U.S. Geological Survey software release, https://doi.org/10.5066/f7x34vzf.

Haines, S.S., Diffendorfer, J.E., Balistrieri, L., Berger, B., Cook, T., Deangelis, D., Doremus, H., Gautier, D.L., Gallegos, T., Gerritsen, M., Graffy, E., Hawkins, S., Johnson, K.M., Macknick, J., McMahon, P., Modde, T., Pierce, B., Schuenemeyer, J.H., Semmens, D., Simon, B., Taylor, J., and Walton-Day, K., 2014, A framework for quantitative assessment of impacts related to energy and mineral resource development: Natural Resources Research, v. 23, no. 1, p. 3–17, https://doi.org/10.1007/s11053-013-9208-6.

107. Geographic Concordance Between Energy Development and Natural or Cultural Resources in Colorado

Identifying locations where potential conflicts between energy development and natural or cultural resources may arise allows more efficient planning of energy development. USGS scientists are creating a statewide geographic analysis overlaying current areas of energy development and areas suitable for future development of wind, solar, and oil/natural gas with geospatial data on natural and cultural resources to identify areas of potential conflicts. This resource can assist resource managers and industry in prioritizing areas for energy development in Colorado.

Contact

Jay Diffendorfer, USGS Geosciences and Environmental Change Science Center, jediffendorfer@usgs.gov, (303) 236–5369

Publication

Macknick, J., Quinby, T., Caulfield, E., Gerritsen, M., Diffendorfer, J., and Haines, S., 2014, Geospatial optimization of siting large-scale solar projects: Golden, Colo., U.S. Department of Energy National Renewable Energy Laboratory, prepared by Joint Institute for Strategic Energy Analysis [JISEA], Technical Report NREL/TP–6A50–61375, https://www.nrel.gov/docs/fy14osti/61375.pdf.

108. Geographic Context in Wind Energy Land Transformation

Land transformation, measured as hectares of surface disturbance per megawatt, associated with wind facilities shows wide variation in its reported values. USGS scientists digitized land transformation at 39 wind facilities by using high-resolution aerial imagery and investigated how turbine size, configuration, land cover, and topography affected the levels of total land transformation. The results indicate that the geographic context in which facilities are installed affects the levels of land transformation associated with wind energy. For example, flat topographies had the lowest land transformation, while facilities on mesas had the largest. This information can assist managers with decisions on how to create opportunities for wind energy production that minimize land-cover change through effective siting. Scientists are now investigating the role of geographic context on road networks and how this affects habitat fragmentation around new facilities.

Contact

Jay Diffendorfer, USGS Geosciences and Environmental Change Science Center, jediffendorfer@usgs.gov, (303) 236–5369

Publication

Diffendorfer, J.E., and Compton, R.W., 2014, Land cover and topography affect the land transformation caused by wind facilities, PLOS ONE, v. 9, no. 2, e87912, https://doi.org/10.1371/journal.pone.0088914.

109. Social Effects Associated With Environmental Change in Coastal Oregon

USGS scientists are assisting BOEM by providing information regarding environmental and human dimensions issues and effects in coastal Oregon. The scientists worked on two case studies situated in areas proximal to two offshore renewable energy lease requests. The studies identified major issues and trends that characterize environmental change in the region; current and potential social, cultural, and economic effects of climate change on Oregon's coastal population and social systems; and information gaps and barriers to policy implementation related to the effects of climate change on human systems with relevance to OCS policymaking. These studies can help inform BOEM's environmental reviews for potential offshore renewable energy projects off Oregon's central coast.

Contact

Rudy Schuster, USGS Fort Collins Science Center, schusterr@usgs.gov, (970) 226–9165

Publication

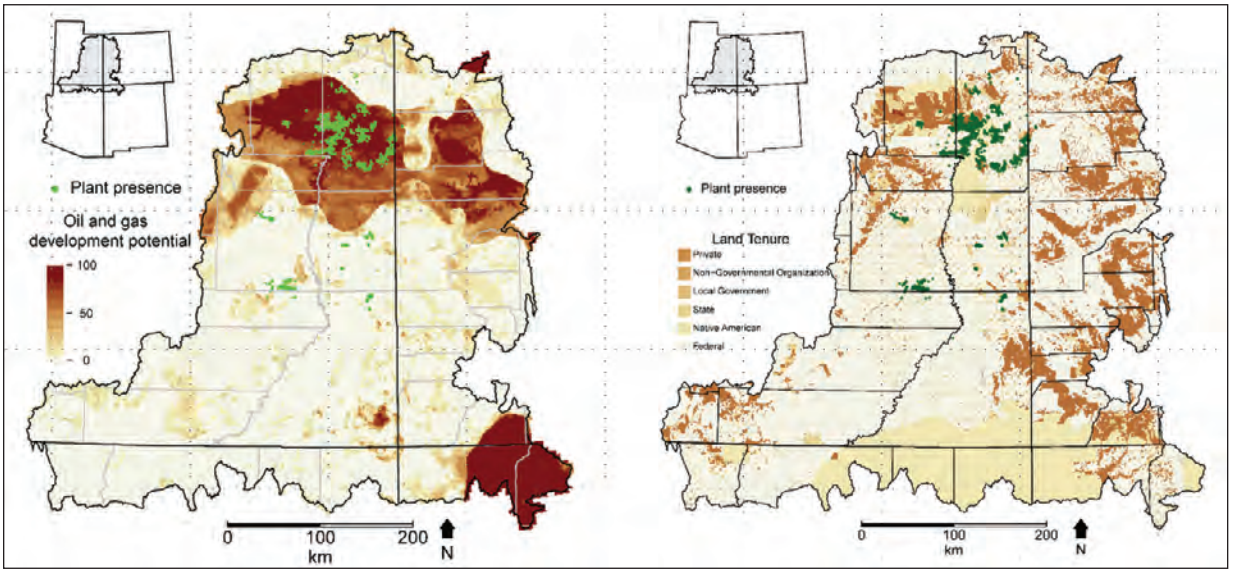
Hoelting, K., and Burkardt, N., 2017, Human dimensions of climate change in coastal Oregon: Washington, D.C., U.S. Department of the Interior, Bureau of Ocean Energy Management, [BOEM], OCS Study BOEM 2017–052, prepared under BOEM Intra-Agency Agreement no. M15PG00008, 216 p., https://www.boem.gov/ESPIS/5/5630.pdf.

110. Sensitive and Rare Plant Distributions and Energy Development in the Colorado Plateau

USGS scientists have developed optimization models to identify lands where management and conservation conflicts between energy development and sensitive and rare plant species could be minimized. As part of this effort, scientists organized existing data on 21 federally listed, rare and sensitive plant species in the Colorado Plateau. Scientists also are collecting new data on plant locations and developing distribution models that indicate the likelihood of plants being present in specified locations. The plant species distribution models are being analyzed in relation to existing and proposed renewable and oil and gas energy development in the Colorado Plateau. Results from this study can help decision makers select variable risk strategies depending on desired management and energy development goals.

Contact

Thomas Edwards, USGS Utah Cooperative Fish and Wildlife Research Unit, t.edwards@nr.usu.edu, (435) 797–2529



Locations of sensitive and rare plants and their overlap (shown in green) with areas of energy potential and land ownership.

Photograph by U.S. Fish and Wildlife Service.

Graham's beardtongue.

Photograph by U.S. Fish and Wildlife Service.

The Uinta Basin hookless cactus is listed as threatened by the Endangered Species Act.

Photograph by John Spence, National Park Service.

The Jones cycladenia is only found on certain geologic formations in Utah and Arizona.

111. Energy Futures for Wyoming

As part of the Wyoming Landscape Conservation Initiative (WLCI), the USGS is mapping the locations and extents of potential electricity-generating resources in Wyoming. This work includes mapping resources, such as natural gas, coal, wind, and hydropower, as well as transmission and transportation corridors. Results of this work can be used to inform the WLCI and other energy-related studies. More broadly, USGS researchers are developing an energy-assessment framework and methods that can be used in other regions.

Contact

Zachary H. Bowen, USGS Fort Collins Science Center, bowenz@usgs.gov, (970) 226–9218

Publications

Bowen, Z.H., Aikens, E., Aldridge, C.L., Anderson, P.J., Assal, T.J., Chalfoun, A.D., Chong, G.W., EddyMiller, C.A., Garman, S.L., Germaine, S.S., Homer, C.G., Johnston, A., Kauffman, M.J., Manier, D.J., Melcher, C.P., Miller, K.A., Walters, A.W., Wheeler, J.D., Wieferich, D., Wilson, A.B., Wyckoff, T.B., and Zeigenfuss, L.C., 2018, U.S. Geological Survey science for the Wyoming Landscape Conservation Initiative—2016 annual report: U.S. Geological Survey Open-File Report 2018–1048, 49 p., https://doi.org/10.3133/ofr20181048.

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Biewick, L.R.H., and Jones, N.R., 2012, Energy map of southwestern Wyoming, Part A—Coal and wind: U.S. Geological Survey Data Series 683, 18 p. pamphlet, 5 pls., https://pubs.usgs.gov/ds/683/.

112. Evaluating Bioenergy Opportunities in the Southwest

The USGS is collaborating with the USDA Arid Land Agricultural Research Center and Ohio University regarding the potential for agave biofuel production to add to our national bioenergy portfolio in marginally productive lands. Agave may represent a highly efficient biofuel, even under nonirrigation conditions, but the ecosystem consequences of this development on drylands, including habitat and wildlife, remain unknown. The project aims to explore the potential benefits and drawbacks of biofuel production in the Southwest as an alternative energy source and strategy.

Contact

Sasha Reed, USGS Southwest Biological Science Center, screed@usgs.gov, (435) 719–2334

Publications

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Photograph by Sasha Reed, U.S. Geological Survey.

Agave plants at a U.S. Department of Agriculture experimental plot site near Phoenix, Arizona.

Additional Publications

Desert Southwest

Moore-O'Leary, K.A., Hernandez, R.R., Johnston, D.S., Abella, S.R., Tanner, K.E., Swanson, A.C., Kreitler, J., and Lovich, J.E., 2017, Sustainability of utility-scale solar energy—Critical ecological concepts: Frontiers in Ecology and the Environment, v. 15, no. 7, p. 385–394, https://doi.org/10.1002/fee.1517.

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Inman, R.D., Esque, T.C., Nussear, K.E., Leitner, P., Matocq, M.D., Weisberg, P.J., and Dilts, T.E., 2016, Impacts of climate change and renewable energy development on habitat of an endemic squirrel, *Xerospermophilus mohavensis*, in the Mojave Desert, U.S.A.: Biological Conservation, v. 200, p. 112–121, https://doi.org/10.1016/j.biocon.2016.05.033.

Kreitler, J., Schloss, C.A., Soong, O., Hannah, L., and Davis, F.W., 2015, Conservation planning for offsetting the impacts of development—A case study of biodiversity and renewable energy in the Mojave Desert: PLOS ONE, v. 10, no. 11, e0140226, https://doi.org/10.1371/journal.pone.0140226.

Inman, R.D., Nussear, K.E., Esque, T.C., Vandergast, A.G., Hathaway, S.A., Wood, D.A., Barr, K.R., and Fisher, R.N., 2014, Mapping habitat for multiple species in the desert Southwest: U.S. Geological Survey Open-File Report 2014–1134, 92 p., https://doi.org/10.3133/ofr20141134.

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Wood, D.A., Vandergast, A.G., Barr, K.R., Inman, R.D., Esque, T.C., Nussear, K.E., and Fisher, R.N., 2012, Comparative phylogeography reveals deep lineages and regional evolutionary hotspots in the Mojave and Sonoran Deserts: Diversity and Distributions, v. 19, no. 7, p. 722–737, https://doi.org/10.1111/ddi.12022.

Atlantic Ocean

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Fatality Estimation Tools

Photograph by Don Becker, U.S. Geological Survey.

A wind farm at sunset.

113. Generalized Fatality Estimator (GenEst) Software and User's Guide

Numerous fatality estimators have been developed to estimate the number of bird and bat fatalities at wind energy facilities, but failure to meet their inherent assumptions can lead to different estimates of fatality. Working with statisticians who developed several of the estimators presently in use, the USGS, BCI, WEST, Inc., and Oregon State University are developing software that combines multiple approaches under a single generalized estimator (GenEst). GenEst will allow the user to evaluate assumptions regarding input parameters and select the approach that best reflects the situation and data. The applicability of GenEst will not be limited to wind power facilities. The tool is being designed for use in any situation in which the objective is an estimate of a super population for which detection probability is unknown but can be estimated, such as solar facilities, oil spills, fisheries by-catch, and power-line or fence-line fatality rates.

Contact

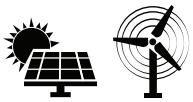
Manuela M. Huso, USGS Forest and Rangeland Ecosystem Science Center, mhuso@usgs.gov, (541) 750–0948

114. Developing a Model to Estimate Golden Eagle Take at Wind Energy Facilities

Simple counts of bird carcasses found at wind energy facilities do not reflect actual fatalities because some carcasses are removed by scavengers or are overlooked by or fall within areas inaccessible to searchers. USGS researchers are using data from white-tailed eagles in Norway as surrogates for U.S. bald and golden eagles that are not found in adequate numbers at any given facility to allow for reliable estimation of eagle-carcass density. The applicability of white-tailed eagle models is being tested using observations from several sites in California. Results can be used by the USFWS in determining take limits for new wind-power facilities and estimating actual eagle take post-construction.

Contact

Manuela M. Huso, USGS Forest and Rangeland Ecosystem Science Center, mhuso@usgs.gov, (541) 750–0948



115. Advances in Estimating Fatalities From Collisions With Energy Infrastructure

Accurate estimates of bird and bat fatalities from collisions with energy infrastructure can be difficult because carcasses may not be detected or may be scavenged. These estimates, however, are critical to understanding the effects of collisions with energy infrastructure on species populations and devising effective methods to mitigate or minimize fatalities. Accurate estimation is complicated because carcasses may fall outside the search area, be removed by scavengers, or be missed by searchers during surveys. The USGS and USFWS are working to develop new tools and improve existing tools to estimate actual bird and bat fatalities based on carcass searches near energy infrastructure. Scientists are also investigating whether accurate and precise estimates of fatalities can be derived from carcass searches conducted at easily accessed areas, such as roads and pads beneath turbines.

Contact

Manuela M. Huso, USGS Forest and Rangeland Ecosystem Science Center, mhuso@usgs.gov, (541) 750–0948

Publications

Huso, M.M., Dalthorp, D.H., and Korner-Nievergelt, F., 2017, Statistical principles of post-construction fatality monitoring design, chap. 4 *in* Perrow, Martin, ed., Wildlife and wind farms, conflicts and solutions, Volume 2, Onshore—Monitoring and mitigation: Exeter, U.K., Pelagic, 227 p.

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Huso, M.M.P., and Dalthorp, D., 2014, Accounting for unsearched areas in estimating wind turbine-caused fatality: Journal of Wildlife Management, v. 78, no. 2, p. 347–358, https://doi.org/10.1002/jwmg.663.

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Dalthorp, D., and Huso, M., 2015, A framework for decision points to trigger adaptive management actions in long-term incidental take permits: U.S. Geological Survey Open-File Report 2015–1227, 88 p., https://doi.org/10.3133/ofr20151227.

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Johnson, D.H., Loss, S.R., Smallwood, K.S., and Erickson, W.P., 2016, Avian fatalities at wind energy facilities in North America—A comparison of recent approaches: Human–Wildlife Interactions, v. 10, no. 1, p. 7–18, http://digitalcommons.usu.edu/hwi/vol10/iss1/3/.

Péron, G., Hines, J.E., Nichols, J.D., Kendall, W.L., Peters, K.A., Mizrahi, D.S., and Matthiopoulos, J., eds., 2013, Estimation of bird and bat mortality at wind-power farms with superpopulation models: Journal of Applied Ecology, v. 50, no. 4, p. 902–911, https://doi.org/10.1111/1365-2664.12100.

Risk Assessment and Management Support Tools

Photograph by Alan Cressler, U.S. Geological Survey.

Wind energy facility in Uinta County, Wyoming.

116. The U.S. Wind Turbine Database

The USGS, in collaboration with the Department of Energy and the American Wind Energy Association (AWEA), updated a national dataset of industry-scale, land-based and offshore wind energy turbines in the United States. The U.S. Wind Turbine Database (https://eerscmap.usgs.gov/uswtdb/) is an interactive web-based tool that is updated quarterly and provides technical specifications, such as turbine height, blade length, rotor, power generation capacity, and year of construction, for most turbines. Turbine locations were obtained from multiple sources and are digitized and spatially verified. This national map of wind turbines can assist regulatory agencies, NGOs, and other decision makers in planning and management activities.

Contact

Jay Diffendorfer, USGS Geosciences and Environmental Change Science Center, jediffendorfer@usgs.gov, (303) 236–5369

Publication

Hoen, B.D., Diffendorfer, J.E., Rand, J.T., Kramer, L.A., Garrity, C.P., and Hunt, H.E., 2018, United States Wind Turbine Database [USWTDB]: U.S. Geological Survey, American Wind Energy Association, and Lawrence Berkeley National Laboratory data release, USWTDB v. 1.0, April 19, https://eerscmap.usgs.gov/uswtdb.

Screenshots from the U.S. Wind Turbine Database mapping application showing locations (top) and technical specifications (bottom) of existing turbines across the continental United States.

117. Review of Bird and Bat Risk From Wind Development

Attempts to measure and mitigate the effects of wind turbines on wildlife have been an integral part of wind energy development. Collision mortality, displacement, and habitat loss can cause population level effects, especially for rare or endangered species. A team of international researchers, including those from the USGS, reviewed studies from Spain, Norway, Canada, the United States, and southern Africa that document the impact of wind energy development on raptors. The researchers gave an overview of raptor species affected by wind farms, discussed monitoring and mitigation strategies, and addressed how studying raptor behavior can inform turbine siting to minimize collision risks. USGS scientists also summarized current pre-construction assessment risks to wildlife from wind turbines, described the number of species and individuals affected by blade-strikes, and discussed how and why pre-construction monitoring is conducted. Several shortcomings were noted in the methods used to assess the risk of fatality at turbines, including the lack of studies to offer evidence for a link between pre-construction surveys and post-construction fatalities.

Contact

Todd E. Katzner, USGS Forest and Rangeland Ecosystem Science Center, tkatzner@usgs.gov, (208) 426–5232

Publications

Watson, R.T., Kolar, P.S., Ferrer, M., Nygård, T., Johnston, N., Hunt, W.G., Smit-Robinson, H.A., Farmer, C.J., Huso, M., and Katzner, T., 2018, Raptor interactions with wind energy—Case studies from around the world: Journal of Raptor Research, v. 52, no. 1, p. 1–18, https://doi.org/10.3356/JRR-16-100.1.

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118. Evaluation of Offshore Radar-Based Monitoring of Flying Animals

The Icebreaker Wind Project is a pilot, six-turbine offshore wind development proposed for western Lake Erie, 8 miles offshore of Cleveland, Ohio. As part of the environmental regulatory process, project developers gather radar data on the use of project airspace by flying animals during the pre- and post-construction period. At the request of the USFWS, the wind developer, and the Lake Erie Energy Development Corporation, USGS scientists evaluated proposed approaches for using radar to track birds and bats in the airspace. The evaluation addresses technical and environmental concerns that bird monitoring associated with other proposed offshore developments may encounter. This assessment helps decision makers implement a best practice approach to evaluating the risk to flying animals near a proposed development site.

Contact

Robb Diehl, USGS Northern Rocky Mountain Science Center, rhdiehl@usgs.gov, (406) 994–7481

119. Reducing Bird and Bat Wind Turbine Strikes Using Weather Radar

USGS scientists are collaborating with the National Renewable Energy Laboratory through a DOE-funded Technology Development and Innovation project on a two-pronged study consisting of a localized field component and a national-level assessment to determine whether the Next Generation Weather Radar (NEXRAD) system can effectively detect wildlife at considerable distances. If this approach is validated, the radar system could then be paired with local visual detection for target identification and be used to alter turbine operations or trigger deterrent systems to reduce wind energy impacts on flying animals.

Photograph by Todd Preston, U.S. Geological Survey.

A USGS scientist is setting up a radar system in Colorado to test its efficacy in detecting birds and bats flying toward spinning wind turbines.

Contact

Robb Diehl, USGS Northern Rocky Mountain Science Center, rhdiehl@usgs.gov, (406) 994–7481

120. Advancing Wildlife Monitoring Technologies Using Weather Surveillance Radar

USGS research in aeroecology relies on advancing radar and other kinds of remote sensing technology to understand the behavior and ecology of flying animals. The USGS is using both historical data and present-day technologies to observe wildlife behaviors in response to changing habitats and landscapes, such as wind and solar energy development and artificial light, as well as ecological barriers and extreme weather events. This research can help with the development of tools designed to predict risks to flying animals.

Contacts

Robb Diehl, USGS Northern Rocky Mountain Science Center, rhdiehl@usgs.gov, (406) 994–7481
Wylie C. Barrow, Jr., USGS Wetland and Aquatic Research Center, barroww@usgs.gov, (337) 266–8668
Deanna Dawson, USGS Patuxent Wildlife Research Center, ddawson@usgs.gov, (301) 497–5642

Photograph by J. Bartholmai, U.S. Geological Survey.

Radar is used to detect the movement patterns and other behaviors of flying animals at night and at distances far beyond the limits of human vision.

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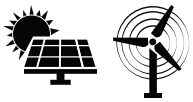

121. Tools to Assess Energy Development Impacts on Sensitive Birds and Bats

A combination of tools is being used to understand how mortality at renewable energy facilities affects populations of sensitive bird and bat species in California. As part of this project, stable isotopes are being used to estimate the geographic scope of the population of birds or bats affected, and demographic modeling is being used to forecast how individual fatalities affect the growth or decline of the species' populations. Development of analytical methods can aid in determining the best practices for conducting risk assessments and predicting mitigation outcomes. Field survey design and protocols are also being developed and integrated with the developed tools. These tools can allow energy developers to more accurately estimate fatality rates and effects of mitigation techniques at wind and solar energy facilities, which may streamline permitting and ultimately reduce costs of energy development.

Contacts

Manuela M. Huso, USGS Forest and Rangeland Ecosystem Science Center, mhuso@usgs.gov, (541) 750–0948
Todd E. Katzner, USGS Forest and Rangeland Ecosystem Science Center, tkatzner@usgs.gov, (208) 426–5232

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122. Evaluating Population-Level Impacts of Wind Energy Development

The impact of wind energy generation on wildlife is commonly approached by monitoring the incidence of mortality resulting from turbine collisions. These mortality events may or may not scale up to observable impacts at a population level. USGS scientists are developing a framework for assessing population-level impacts of wind energy by using abundance time-series data and turbine location maps. The two-part approach first examines whether the timing and placement of turbines on the landscape are coincident with observed population trends at regional scales by using dynamic factor analysis. Next, localized impacts are examined by comparing population trends from sampling locations near wind turbine development with relatively distant locations by using Bayesian structural time-series models. This research can assist conservation managers with wind energy project permitting and the use and interpretation of monitoring protocols for wind facilities.

Contacts

Jay Diffendorfer, USGS Geosciences and Environmental Change Science Center, jediffendorfer@usgs.gov, (303) 236–5369
Wayne E. Thogmartin, USGS Upper Midwest Environmental Science Center, wthogmartin@usgs.gov, (608) 781–6309

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123. Structured Decision Making: Decision Support Frameworks and Tools for Conservation

Structured decision making (SDM) is an approach for careful and organized analysis of natural resource management decisions. SDM encompasses a set of concepts and steps based on decision theory and risk analysis, including making decisions on the basis of clearly articulated fundamental objectives, recognizing the role of scientific predictions in decisions, dealing explicitly with uncertainty, and responding transparently to societal values in decision making. This approach can be used to address a variety of resource management decisions related to the operation and management of energy infrastructure, including the long-term management of the Glen Canyon Dam in northern Arizona.

Photograph by Kyrie Fry, U.S. Geological Survey.

Colorado River downstream from the Glen Canyon Dam.

Contact

Michael Runge, USGS Patuxent Wildlife Research Center, mrunge@usgs.gov, (301) 497–5748

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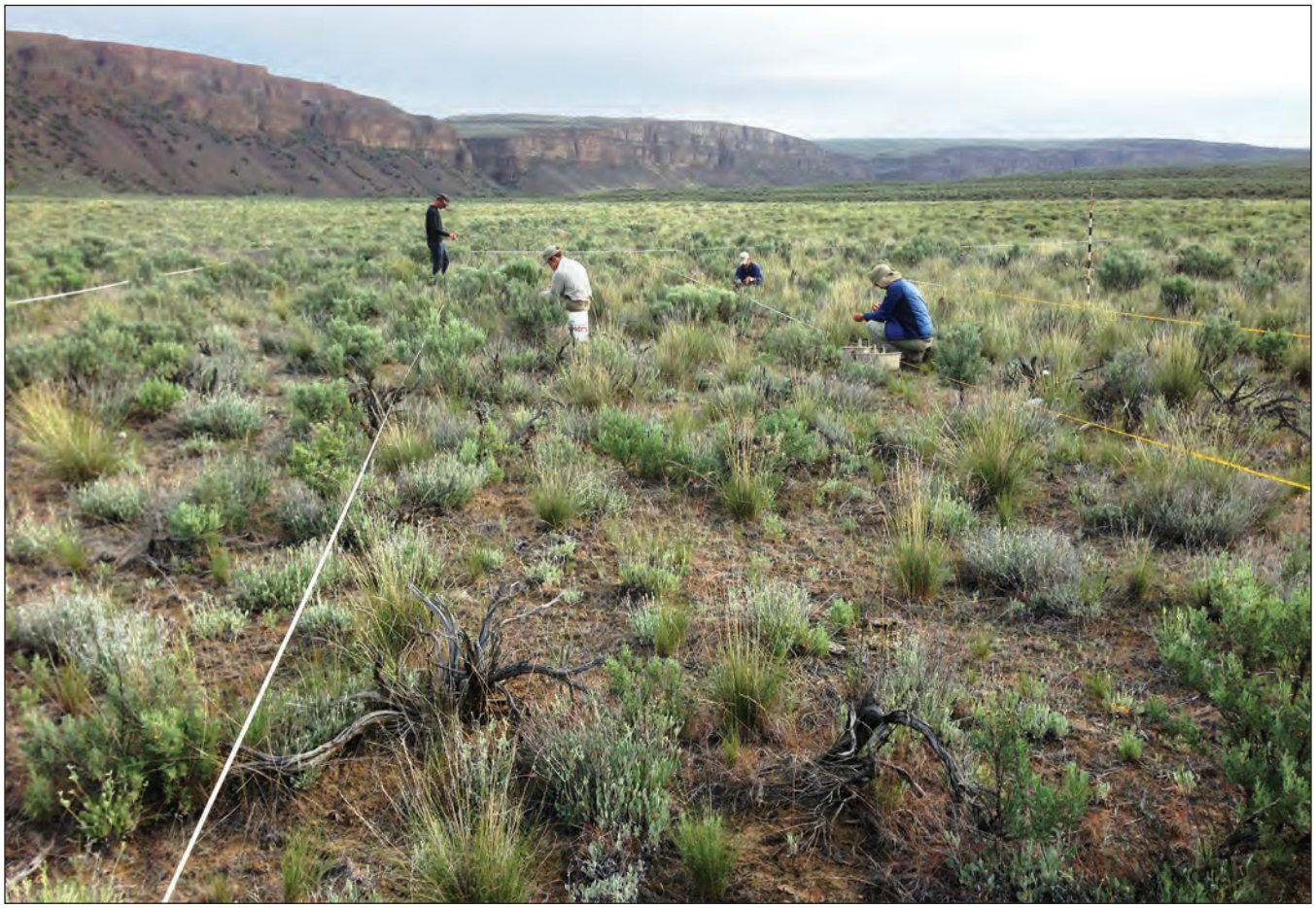
Recovery and Restoration Following Development



Photograph by Scott Shaff, U.S. Geological Survey.

USGS scientists collecting vegetation data for a regional experiment evaluating methods of sagebrush steppe restoration.

Wyoming and the Colorado Plateau

124. Evaluating Reclamation Success Following Oil and Gas Development

USGS scientists developed new approaches to regional assessments of land recovery following oil and gas drilling activities and resulting dust generation. These new approaches can help resource managers make informed decisions for future well pad and infrastructure development. The approaches incorporate satellite imagery, digital soil mapping, predictive ecological modeling, and field assessments to evaluate vegetation recovery following well pad abandonment and dust production for unpaved road networks. Scientists studied more than 1,800 well pads in Utah, Colorado, and New Mexico. Results suggest that unpaved roads and plugged and abandoned well pads have about seven times more windblown sediment transport than rangelands in dryland areas, but also show variation between local soil types and vegetation communities where wells and roads are located. Analysis of archival satellite imagery showed that most abandoned oil and gas well pads in the study were characterized by more bare ground and less perennial vegetation than surrounding undisturbed areas, even more than 9 years after well abandonment. Differing recovery rates across environmental gradients and under varied land stewardship suggest that these findings can be useful to managers in identifying conditions that may promote or hamper well pad recovery.

Contacts

Michael Duniway, USGS Southwest Biological Science Center, mduniway@usgs.gov, (928) 556–7530
Miguel Villarreal, USGS Western Geographic Science Center, mvillarreal@usgs.gov, (650) 329–4261

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125. Modeling Recovery of Sagebrush Ecosystems Using Remotely Sensed Vegetation Products

Much of our current understanding of sagebrush restoration relies on results from localized studies that yield limited inferences for other locations and do not provide an understanding of spatial and temporal factors influencing recovery across the landscape. USGS scientists developed a framework for modeling change in sagebrush cover on reclaimed well pads by using time-varying, remote-sensing products developed for the WLCI. This approach allows managers to predict rates of sagebrush recovery across broad scales and assess the effects of factors such as weather and soils on outcomes.

Contacts

Cameron Aldridge, USGS Fort Collins Science Center, aldridge@usgs.gov, (970) 226–9433
Adrian Monroe, USGS Fort Collins Science Center, amonroe@usgs.gov, (970) 226–9122

126. Understanding Drought-Stress in Sagebrush Ecosystems Associated With Energy Development

The USGS, working with WLCI partners, is investigating the recovery of sagebrush ecosystems exposed to recent drought in the Upper Green River Basin, Wyoming. Scientists are using satellite data to understand decadal patterns of productivity and detect monthly anomalies associated with drought-related mortality to document the extent and severity of the disturbance. Scientists are also producing maps that highlight areas for plant community assessment. This information can be used by resource managers to assess the recovery of sagebrush ecosystems exposed to multiple stressors such as drought and energy development.

Contacts

Timothy Assal, USGS Fort Collins Science Center, assalt@usgs.gov, (970) 226–9134
Pat Anderson, USGS Fort Collins Science Center, andersonpj@usgs.gov, (970) 226–9488

Publication

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127. Wyoming Wind Energy Disturbance Mapping

USGS scientists are quantifying, for the WLCI, land-surface disturbance associated with development and operation of wind facilities. In this analysis, scientists are incorporating all infrastructure data associated with wind energy development, surface disturbance, and re-vegetation or reclamation following initial wind-facility development. Results will document the amount and pattern of disturbance over time during the development and operation of facilities in Wyoming. This information may be useful to developers and land managers in planning and assessing future wind projects.

Contact

Aaron Johnston, USGS Northern Rocky Mountain Science Center, ajohnston@usgs.gov, (406) 994–7158

Desert Southwest

128. Ecological Restoration and Native Plant Development in Hot Desert Systems

Energy development across the Mojave and Sonoran Deserts has increased the demand for more effective restoration techniques and appropriate plant materials for seeding and planting disturbed areas. In collaboration with Rancho Santa Ana Botanical Garden, Texas State University, BLM, and USFWS, the USGS developed seed-transfer zones at a resolution appropriate to guide seed-collection activities across the Mojave Desert. A network of experimental gardens incorporates research on germination, establishment, and survivorship with landscape genetics and physiology on a variety of key native plant species.

Contacts

Lesley DeFalco, USGS Western Ecological Research Center, ldefalco@usgs.gov, (702) 564–4507
Todd Esque, USGS Western Ecological Research Center, tesque@usgs.gov, (702) 564–4506

Publications

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Aquatic Habitat Restoration and Dam Removal

129. Reintroduction of Anadromous Salmonids to Reservoirs Above Hydroelectric Dams

USGS scientists evaluated the feasibility of reintroducing native salmonids to hydropower reservoirs in Washington State to determine if the reservoirs could support reintroduced populations of salmonids. These reservoirs serve both as functional migration corridors and profitable juvenile-rearing habitats despite hosting abundant predator populations. The scientists evaluated consumption demand and seasonal food availability as well as potential predation mortality to juvenile anadromous salmonids. This approach can assist fisheries managers and power operators by identifying options for design and operations of hydropower facilities that could balance power demand with increased fish production.

Image from video clip by Kyle Martens, edited by Rachel Reagan, U.S. Geological Survey.

Juvenile Chinook salmon in Cougar Reservoir in the Willamette Basin.

Contact

David A. Beauchamp, USGS, Western Fisheries Research Center, fadave@usgs.gov, (206) 526–6596

Publications

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130. Natural Salmon Recolonization Following Dam Removal

Condit Dam on the White Salmon River in Washington State was breached in 2011 and removed completely in 2012, allowing anadromous salmonids access to habitat that had been blocked for nearly 100 years. A multiagency workgroup concluded that the preferred salmonid restoration alternative was natural recolonization with monitoring to assess efficacy, followed by a management evaluation 5 years after dam removal. In 2016, USGS scientists, in cooperation with the Mid-Columbia Fisheries Enhancement Group, assessed juvenile salmonid diversity, distribution, and abundance. The 2016 effort provided the first post-dam smolt and juvenile abundance estimates for coho salmon and steelhead in the White Salmon River as well as the first documentation of coho salmon juvenile production in tributaries upstream from the former Condit Dam site. This monitoring effort can help to better understand abundance trends, distribution, and life history patterns of recolonizing salmonids and assess efficacy of natural recolonization to inform management decisions.

Contacts

Jill Hardiman, USGS Western Fisheries Research Center, jhardiman@usgs.gov, (509) 538–2906
Ian Jezorek, USGS Western Fisheries Research Center, ijezorek@usgs.gov, (509) 538–2908

Publications

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131. Dam Removal and Fish Passage Improvements on the Penobscot River

Restoration efforts on the Penobscot River, Maine, are among the largest recently completed in the United States and include the removal of the lower two dams and improvements to fish passage at several remaining barriers. USGS and partners assessed fish assemblages in the main-stem river and several major tributaries before (2010–12) and after (2014–16) dam removal to monitor changes in fish assemblage composition in reaches that had undergone both habitat and connectivity changes. Results of these studies demonstrate the potential for large dam removal projects to restore both fluvial and anadromous fish assemblages, while maintaining energy production.

Contact

Joseph Zydlewski, USGS Maine Cooperative Fish and Wildlife Research Unit, josephz@maine.edu, (207) 581–2853

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132. Ecological Effects of the Elwha River Dam Removal

After nearly a century of power production, two large hydroelectric dams on the Elwha River in Washington State were removed during 2011–14 to restore the river ecosystem and recover economic and culturally important salmon populations. About two-thirds of the 21 million cubic meters of sediment—enough to fill nearly 2 million dump trucks—contained behind the dams was released downstream, restoring natural processes and initiating important changes to the river, estuarine, and marine ecosystems. A multidisciplinary team of scientists from the Lower Elwha Klallam Tribe, academia, NGOs, Federal and State agencies, and the USGS collected data before, during, and after dam removal to understand the outcomes of the project on the Elwha River ecosystem. This information can be used to inform future large-scale dam removal projects.

Contact

Jeff Duda, USGS Western Fisheries Research Center, jduda@usgs.gov, (206) 526–2532

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List of Species

Common name	Scientific name
Agassiz's desert tortoise	*Gopherus agassizii*
Agave	*Agave Americana*
Alewife	*Alosa pseudoharengus*
American eel	*Anguilla rostrata*
American shad	*Alosa sapidissima*
Ashy storm-petrel	*Oceanodroma homochroa*
Atlantic salmon	*Salmo salar*
Atlantic sturgeon	*Acipenser oxyrinchus oxyrinchus*
Bald eagle	*Haliaeetus leucocephalus*
Bighead carp	*Hypophthalmichthys nobilis*
Black scoter	*Melanitta nigra*
Black storm-petrel	*Oceanodroma melania*
Black-tailed jackrabbit	*Lepus californicus*
Blueback herring	*Alosa aestivalis*
Brook trout	*Salvelinus fontinalis*
Brown pelican	*Pelecanus occidentalis*
Brown trout	*Salmo trutta*
Bull trout	*Salvelinus confluentus*
Burrowing owl	*Athene cunicularia*
California condor	*Gymnogyps californianus*
Caribou	*Rangifer tarandus*
Chinook salmon	*Oncorhynchus tshawytscha*
Coho salmon	*Oncorhynchus kisutch*
Common loon	*Gavia immer*
Common merganser	*Mergus merganser*
Common raven	*Corvus corax*
Desert tortoise	*Gopherus agassizii*
Dixie Valley toad	*Anaxyrus williamsi*
Eastern red bat	*Lasiurus borealis*
Elegant tern	*Thalasseus elegans*
Elk	*Cervus canadensis*
Florida manatee	*Trichechus manatus latirostris*
Golden eagle	*Aquila chrysaetos*
Grasshopper sparrow	*Ammodramus savannarum*
Greater prairie-chicken	*Tympanuchus cupido*
Greater sage-grouse	*Centrocercus urophasianus*
Greater scaup	*Aythya marila*
Greater white-fronted goose	*Anser albifrons*
Green sea turtle	*Chelonia mydas*
Gulf sturgeon	*Acipenser oxyrinchus*
Harlequin duck	*Histrionicus histrionicus*
Hawaiian hoary bat	*Lasiurus cinereus semotus*
Hawaiian petrel	*Pterodroma sandwichensis*
Hoary bat	*Lasiurus cinereus*
Honey bee	*Apis mellifera*
Horned grebe	*Podiceps auritus*
Horned lark	*Eremophila alpestris*
Humpback chub	*Gila cypha*
Indiana bat	*Myotis sodalis*
Kemp's ridley	*Lepidochelys kempii*
Lake sturgeon	*Acipenser fulvescens*
Least tern	*Sternula antillarum*
Lesser prairie-chicken	*Tympanuchus pallidicinctus*
Lesser scaup	*Aythya affinis*
Loggerhead	*Caretta caretta*
Long-eared owl	*Asio otus*
Long-tailed duck	*Clangula hyemalis*
Louisiana waterthrush	*Parkesia motacilla*
McCown's longspur	*Rhynchophanes mccownii*
Meadow fritillary	*Boloria bellona*
Mexican free-tailed bat	*Tadarida brasiliensis*
Mohave ground squirrel	*Xerospermophilus mohavensis*
Mule deer	*Odocoileus hemionus*
Muskox	*Ovibos moschatus*
Northern gannet	*Morus bassanus*
Northern long-eared bat	*Myotis septentrionalis*
Northern pikeminnow	*Ptychocheilus oregonensis*
Pacific blue mussel (foolish mussel)	*Mytilus trossulus*
Pacific loon	*Gavia pacifica*
Pacific walrus	*Odobenus rosmarus divergens*
Piping plover	*Charadrius melodus*
Polar bear	*Ursus maritimus*
Pronghorn	*Antilocapra americana*
Pygmy rabbit	*Brachylagus idahoensis*
Quagga mussel	*Dreissena bugensis*
Rainbow trout	*Oncorhynchus mykiss*
Red-breasted merganser	*Mergus serrator*
Red-necked grebe	*Podiceps grisegena*
Red swamp crayfish	*Procambarus clarkii*
Red-tailed hawk	*Buteo jamaicensis*
Red-throated loon or red-throated diver	*Gavia stellata*
Roseate tern	*Sterna dougallii*
Round goby	*Neogobius melanostomus*
Rusty crayfish	*Orconectes rusticus*
Rusty patched bumble bee	*Bombus affinis*
Sage grouse	*Centrocercus urophasianus*
Sandhill crane	*Grus canadensis*
Scripps's murrelet	*Synthliboramphus scrippsi*
Sea lamprey	*Petromyzon marinus*
Sea otter	*Enhydra lutris*
Sharp-tailed grouse	*Tympanuchus phasianellus*
Silver carp	*Hypophthalmichthys molitrix*
Silver-haired bat	*Lasionycteris noctivagans*
Snow geese	*Chen caerulescens*
Sockeye salmon	*Oncorhynchus nerka*
Sooty shearwater	*Puffinus griseus*
Steelhead	*Oncorhynchus mykiss*
Surf scoter	*Melanitta perspicillata*
Swainson's hawk	*Buteo swainsoni*
Western toad	*Anaxyrus boreas*
White-tailed eagle	*Haliaeetus albicilla*
White-tailed jackrabbit	*Lepus townsendii*
White-winged scoter	*Melanitta deglandi*
Whooping crane	*Grus americana*
Yellow-billed loon	*Gavia adamsii*
Zebra mussel	*Dreissena polymorpha*

Conifer woodland. Photograph by Steven Hanser, U.S. Geological Survey.

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For additional information regarding this publication, please contact:
Mona Khalil mkhalil@usgs.gov

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