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U.S. Geological Survey Energy and Wildlife Research Annual Report for 2019

Circular 1458

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

Cover. Top left: Wind energy facility in White Pine County, Nevada (photograph by Alan Cressler, U.S. Geological Survey [USGS]). Top right: Solar energy facility in Colorado (photograph by Jessica Robertson, USGS). Bottom left: Oil production in Montana (photograph by Lawrence Igl, USGS). Bottom right: Hydroelectric power plant in Glendo State Park, Wyoming (photograph from Wikimedia, Creative Commons 3.0). Center from top to bottom: Golden eagle fitted with Global Positioning System backpack (photograph by USGS); Hawaiian hoary bat (photograph by Frank Bonaccorso, USGS); Pronghorn (photograph by National Park Service); Brook trout (photograph by U.S. Fish and Wildlife Service).

U.S. Geological Survey Energy and Wildlife Research Annual Report for 2019

Edited by Mona Khalil

Three caribou standing in the tundra in Alaska. Photograph by Andrew Ramey, U.S. Geological Survey.

Circular 1458

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

U.S. Department of the Interior
DAVID BERNHARDT, Secretary

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

U.S. Geological Survey, Reston, Virginia: 2019

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Abbreviations

AWEA	American Wind Energy Association
BCI	Bat Conservation International
BLM	Bureau of Land Management
BOEM	Bureau of Ocean Energy Management
BSEE	Bureau of Safety and Environmental Enforcement
DEEP SEARCH	Deep-Sea Exploration to Advance Research on Coral/Canyon/Cold Seep Habitats
DNA	deoxyribonucleic acid
DOE	U.S. Department of Energy
DOI	U.S. Department of the Interior
DWH	Deepwater Horizon
eDNA	Environmental DNA
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	Global Positioning System
GPS-GSM	Global Positioning System-Global System for Mobile communications
MFTB	Mexican free-tailed bats
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
RAMPS	Restoration Assessment and Monitoring Program for the Southwest
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

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Science to Understand Risks, Measure Impacts, and Inform Solutions

Access to affordable and reliable energy remains a critical need for people and the economy. To satisfy society's demand for energy, the United States is expanding access to vast natural resources to produce electricity as well as petroleum and natural gas products. Oil and gas production and wind and solar energy generation have shown consistent growth over the last 15 years. Currently, more than 59,000 wind turbines are contributing to power grids in 41 States, Guam, and Puerto Rico (American Wind Energy Association, 2019; Hoen and others, 2019), and more than 9,200 ground-mounted solar projects with a capacity of 1 megawatt and above are in operation, under construction, or under development (Solar Energy Industries Association, 2019).

Development of our Nation's vast energy resources, however, often conflicts directly with the equally vast fish and wildlife resources, which contribute billions of dollars to the economy through harvest, recreation, and services to humans and agriculture. The effects of energy development on living resources include fragmentation of populations, degradation or loss of habitat, and direct mortality of birds, bats, fish, and other wildlife interacting with energy generation facilities. Thus, an expanding energy infrastructure results in new requirements for land and ocean conversion for project siting and operational decisions to minimize risk to fish and wildlife resources.

The U.S. Geological Survey (USGS) is a bureau within the U.S. Department of the Interior (DOI). The USGS mission is to provide 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. USGS scientists partner with more than 150 Federal, State, and local government agencies; Tribal nations; academic institutions; and nongovernmental organizations (NGOs) to deliver timely and relevant information on pressing resource management issues. This information helps decision makers balance development with stewardship of the Nation's fish and wildlife heritage. USGS studies related to energy development focus on delivering information to help resource managers and energy developers avoid, minimize, or mitigate the impacts of energy infrastructure on fish and wildlife. These studies have three primary goals:

1. Understand risks by identifying when, where, and how fish and wildlife share space with energy facilities.
2. Measure direct and indirect impacts to species and habitats.
3. Inform feasible and cost-effective solutions to minimize impacts through technology and management strategies.

Progress and Updates to the Annual Report

This report summarizes ongoing USGS research projects and publications related to the impacts of energy development on fish and wildlife resources, tools to assess those impacts, and solutions to avoid or minimize risk. These studies are funded through a combination of Congressionally appropriated funds to the USGS and supplemental contributed funds from USGS partners, including other Federal and State resource management agencies.

This year's report features geospatial models and tools for species and habitats that were produced to assist resource managers and the industry in siting new energy development and selecting off-site mitigation areas. Research efforts are applied to oil and gas development activities, where USGS tools can identify areas of lowest conflict between energy development and sensitive resources, such as trust and at-risk species, and provide management solutions that improve the recovery of species and landscapes altered by energy extraction. To address wildlife concerns related to wind energy development, the USGS is working with stakeholders and industry to develop technologies and management solutions to

maximize wind-facility development and energy production while reducing wildlife fatalities at wind farms. USGS scientists are testing bat deterrent devices and operational management strategies that allow companies to meet guidelines and remain productive. To address emerging wildlife issues related to utility-scale solar energy, the USGS assists land and wildlife managers, industry, and other stakeholders by identifying the causes of negative effects to animals and the areas where impacts can be minimized. Finally, to improve aquatic ecosystems and species recovery, USGS scientists are designing next-generation fish passage devices for hydropower dams that can replace those reaching the end of their lifespans, improve migratory fish passage, and reduce spread of invasive species.

Renewable energy development in the desert Southwest presents challenges to the threatened desert tortoise. New research quantifies the risks of such activities. Photograph by Todd C. Esque, U.S. Geological Survey.

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, National Park Service (NPS), 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.

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Energy Icons

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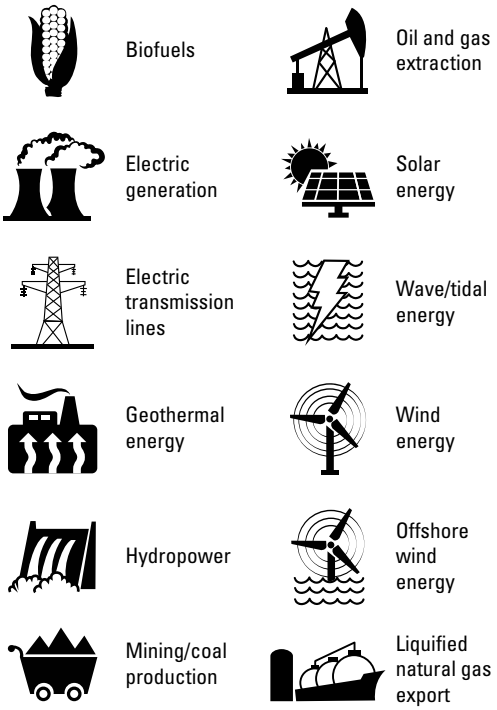
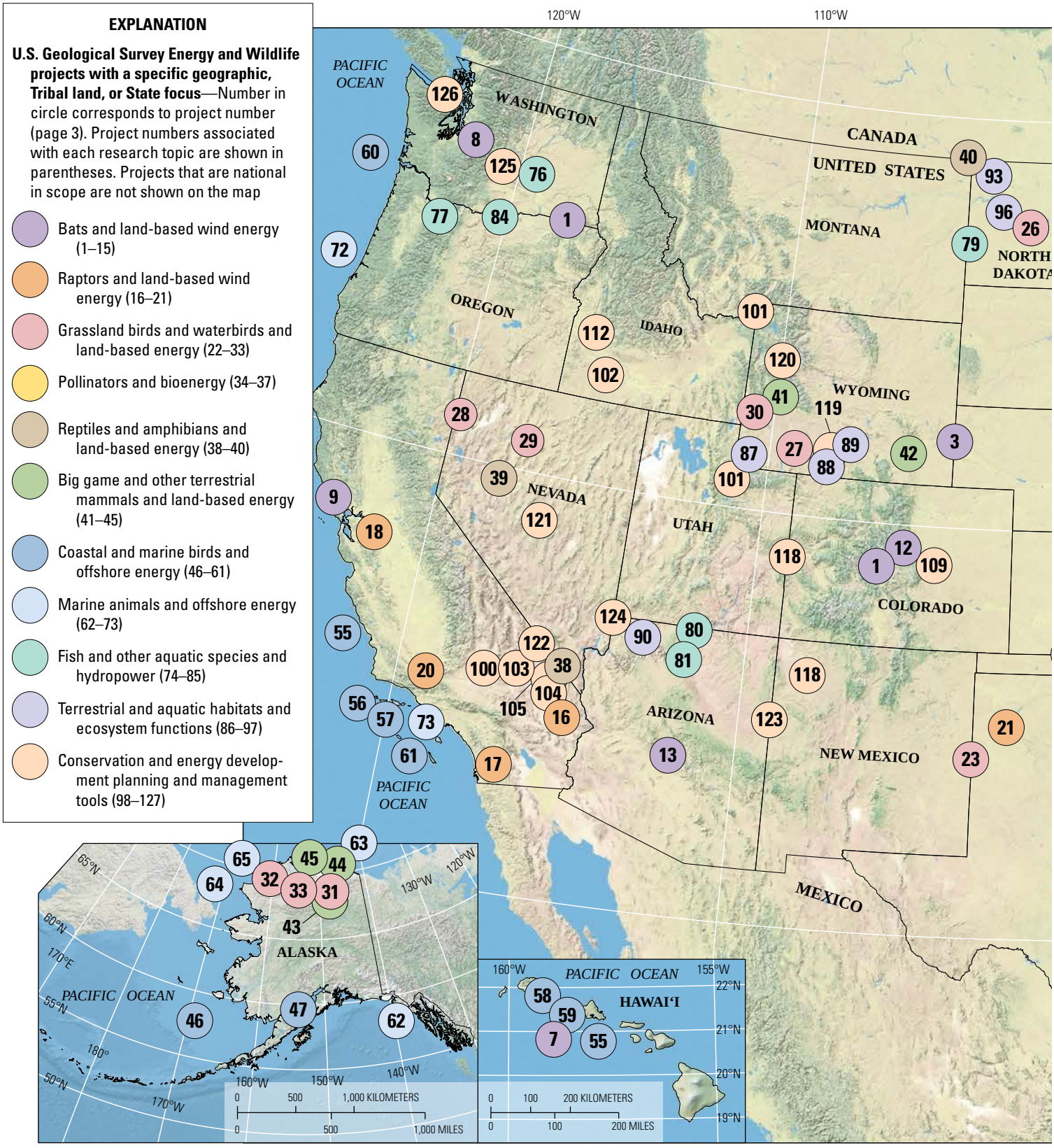


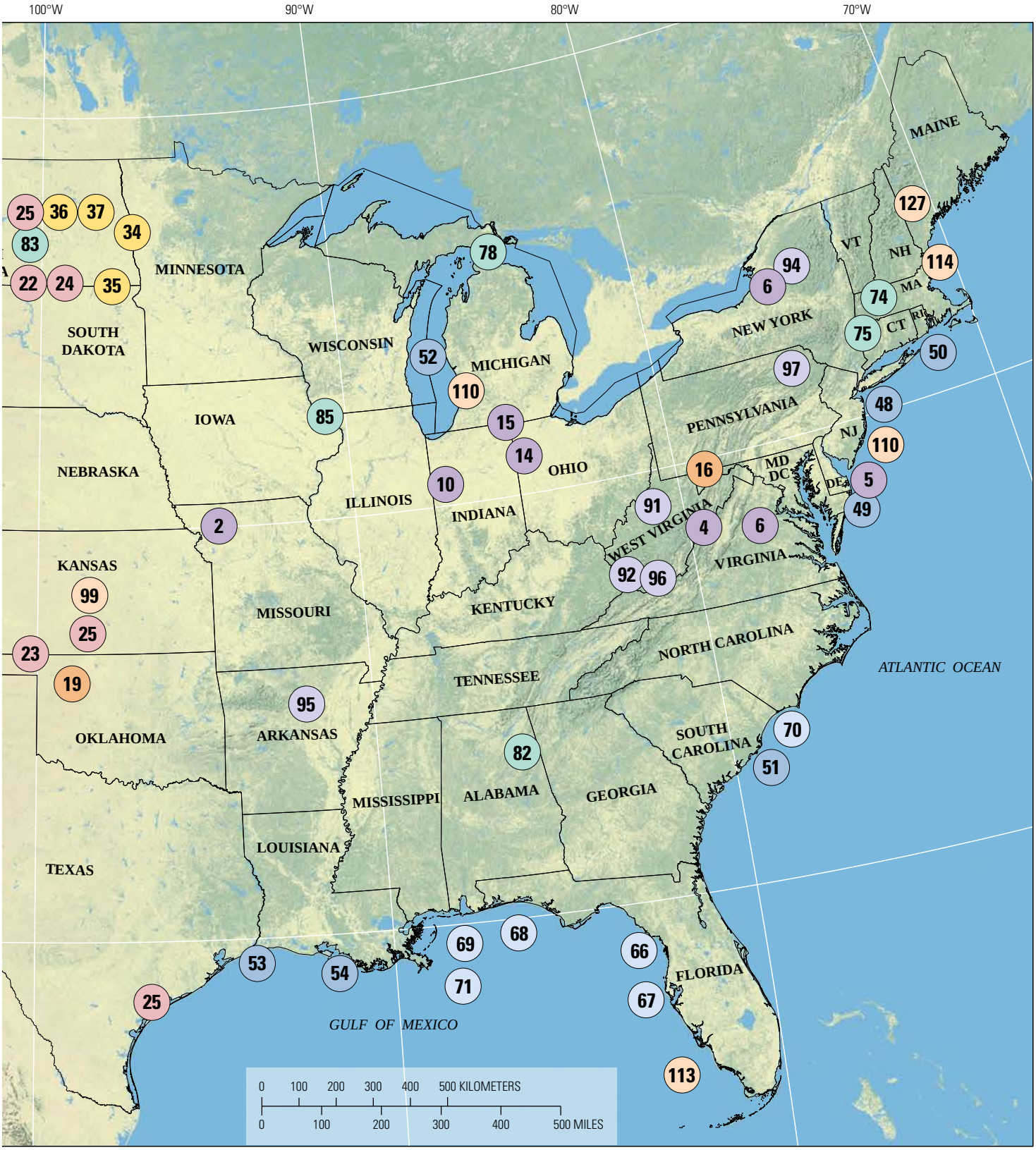
Icons modified from BSGStudio, all-free-download.com.
Geothermal energy icon from icons8.com.

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



Map image is the intellectual property of Esri and is used herein under license. Copyright © 2014 Esri and its licensors. All rights reserved. Universal Transverse Mercator projection, zone 14


100°W
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NJ
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DC
DE
WEST VIRGINIA
VIRGINIA
NORTH CAROLINA
SOUTH CAROLINA
GEORGIA
FLORIDA
ALABAMA
MISSISSIPPI
TENNESSEE
KENTUCKY
OHIO
INDIANA
ILLINOIS
MICHIGAN
WISCONSIN
MINNESOTA
IOWA
MISSOURI
ARKANSAS
LOUISIANA
TEXAS
OKLAHOMA
KANSAS
NEBRASKA
SOUTH DAKOTA
ATLANTIC OCEAN
GULF OF MEXICO
0 100 200 300 400 500 KILOMETERS
0 100 200 300 400 500 MILES

Wheat field with wind turbines in Wyoming. Photograph by Paul Cryan, U.S. Geological Survey.

Project Descriptions

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

Bats emerging from the trees in the early evening sky.

Bats and Land-Based Wind Energy

Insect-eating bats provide pest control and pollination services worth billions of dollars to farmers annually (Boyles and others, 2011), but bat populations nationwide are being threatened by an invasive fungal disease (white-nose syndrome; WNS), wind turbines (Cryan and others, 2014), habitat loss, and other stressors. The projects listed below describe USGS studies on bat migration and distribution, bat behavior near wind turbines, strategies and tools to deter bats from turbines, and statistical methods to assess bat fatalities. This research, combined with studies on the cause, distribution, and control techniques of WNS, assist State and Federal land managers and the energy industry to site and manage wind farms to reduce conflict between bats and wind energy production.

Bat Migration and Distribution

1. The North American Bat Monitoring Program (NABat)

The USGS leads the North American Bat Monitoring Program (NABat; https://nabatmonitoring.org/), a multiorganizational program whose participants include State and Federal agencies, Native American tribes, universities, NGOs, and private industry partners such as Duke Energy. NABat members work to better understand the health of North America's bat populations, including current and future impacts from WNS and wind energy. The mission of NABat 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 acoustic recordings collected at or near wind energy facilities. Thus far, NABat monitoring data have been collected in 47 States and 10 Canadian Provinces. In 2019, new analyses are planned to provide information on status and trends in occurrence of hoary bats and little brown bats across the Pacific Northwest and baseline distribution maps for 18 species in Colorado and 6 species in South Carolina. Additional products will include the first protocol for NABat that includes detailed standard operating procedures for detector deployment and other necessary specifications for defensible statistical analyses.

Contact

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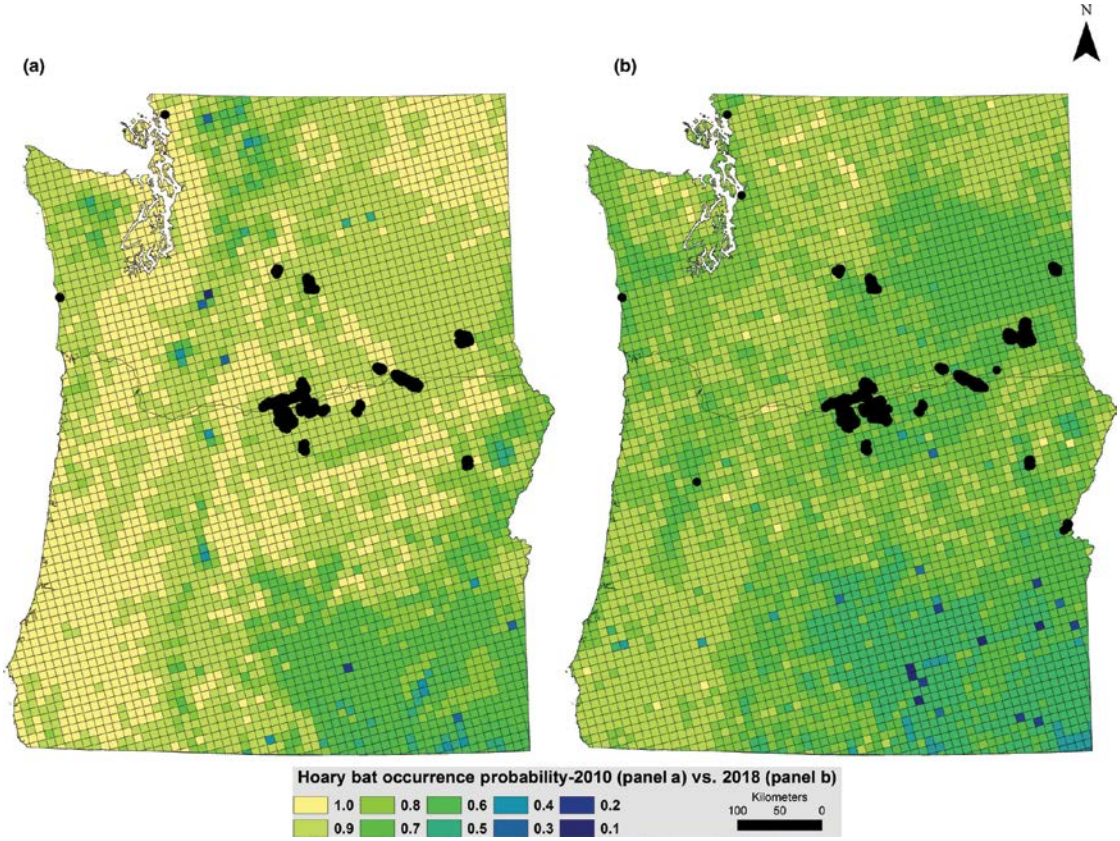

Hoary bat predicted occurrence probability maps for Oregon and Washington for (a) 2010 and (b) 2018. Image from Rodhouse and others (2019), Creative Commons 4.0 license.

Publications

Banner, K.M., Irvine, K.M., Rodhouse, T.J., Donner, D., and Litt, A.R., 2019, Online supporting information for "Statistical power of dynamic occupancy models to identify temporal change—Informing the North American Bat Monitoring Program": U.S. Geological Survey software release, https://doi.org/10.5066/P9WHOH6D.

Banner, K.M., Irvine, K.M., Rodhouse, T.J., Donner, D., and Litt, A.R., 2019, Statistical power of dynamic occupancy models to identify temporal change—Informing the North American Bat Monitoring Program: Ecological Indicators, v. 105, p. 166–176, https://doi.org/10.1016/j.ecolind.2019.05.047.

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Reichert, B., Lausen, C., Loeb, S., Weller, T., Allen, R., Britzke, E., Hohoff, T., Siemers, J., Burkholder, B., Herzog, C., and Verant, M., 2018, A guide to processing bat acoustic data for the North American Bat Monitoring Program (NABat): U.S. Geological Survey Open-File Report 2018–1068, 33 p., https://doi.org/10.3133/ofr20181068.

Rodhouse, T.J., Rodriguez, R.M., Banner, K.M., Ormsbee, P.C., and Irvine, K.M., 2019, Evidence of region-wide bat population decline from long-term monitoring and Bayesian occupancy models with empirically informed priors: Ecology and Evolution, early view, posted September 11, 2019, 11 p., https://doi.org/10.1002/ece3.5612.

Rodriguez, R.M., Rodhouse, T.J., Barnett, J., Irvine, K.M., Banner, K.M., Lonnecker, J., and Ormsbee, P.C., 2019, North American Bat Monitoring Program regional protocol for surveying with stationary deployments of echolocation recording devices: Fort Collins, Colo., U.S. Department of the Interior, National Park Service, Natural Resource Report NPS/UCBN/NRR—2019/1975, 33 p., https://irma.nps.gov/DataStore/Reference/Profile/2265647.

2. Indiana Bat Maternity Habitat Requirements in Missouri

Wind turbine collisions and white-nose syndrome (WNS) can intensify the decline of endangered Indiana bat populations in the Midwestern United States. To better understand summer habitat requirements and drivers of Indiana bat maternity roost selection, the USGS partnered with the USFWS to examine maternity habitat selection in national wildlife refuges in Missouri. The project is evaluating broad-scale habitat associations, such as a preference for bottomland hardwood forests in close proximity to water, as well as testing for the differences in habitat characteristics between primary and alternate roosts. Scientists are examining differences in tree size and canopy cover between primary and alternate roosts and the role of temperature in influencing use of primary or alternate roosts. Results can provide new information on the importance of alternate roosts and smaller interior snags to the health and survival of maternity colonies.

Contact

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3. Bat Conservation and Recovery in Nebraska and Wyoming

There are mounting concerns for North American bats due to continuing and emerging threats from disease, habitat loss and fragmentation, and wind energy development. Because these threats are likely to increase in severity, there is an opportunity to improve the resiliency of summer bat habitats, learn how these threats impact local bat populations, and establish regional monitoring that can inform local and national resource management decisions. The USGS is collaborating with the Nebraska Game and Parks Commission, the Wyoming Game and Fish Department, and State and Federal natural resource managers in the Midwest to develop a strategic approach to bat conservation across Wyoming and Nebraska by monitoring impacts of disease, habitat fragmentation, and wind energy development on bat populations to provide decision makers with decision support tools and a bat conservation plan.

Contact

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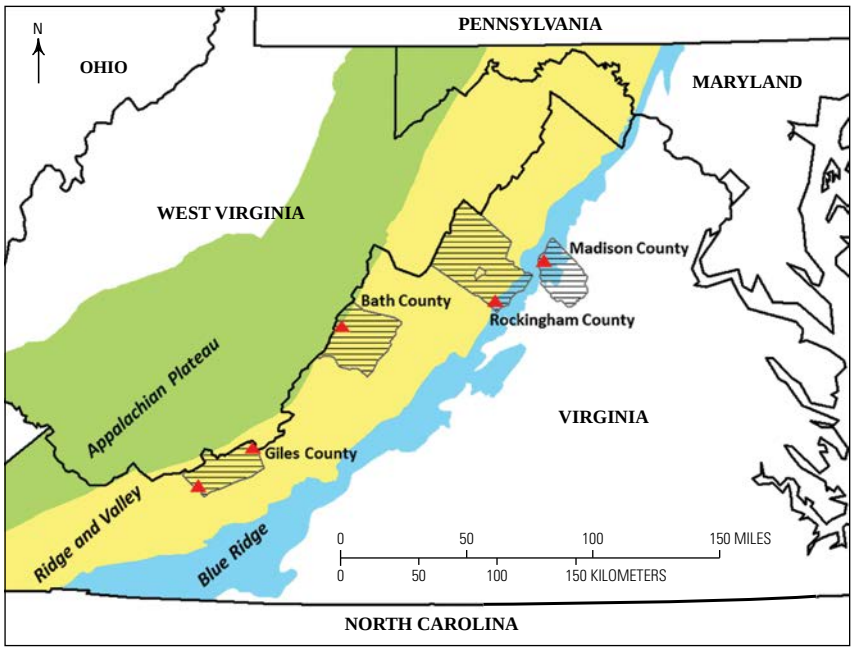
4. Pre- and Post-Hibernation and Migratory Activity of Bats in the Central Appalachians

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 were 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.



Approximate locations of five ridges sampled in the central Appalachians of Virginia (from Muthersbaugh and others, 2019).

Contact

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Publication

Muthersbaugh, M.S., Ford, W.M., Powers, K.E., and Silvis, A., 2019, Activity patterns of bats during the fall and spring along ridgelines in the central Appalachians: Journal of Fish and Wildlife Management, v. 10, no. 1, p. 180–195, https://doi.org/10.3996/082018-JFWM-072.

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

Scientists from the Virginia Department of Game and Inland Fisheries, the 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 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. Long-term acoustic data collected year-round at various coastal sites provide additional insight. Initial results regarding nano-tag retention time and bat migratory movements are being analyzed to help guide full-scale deployment in 2019 and 2020. As in the Appalachian region, long-term acoustic data suggest that migratory bat movements in the coastal areas are influenced by seasonal and weather interactions.

Contact

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6. 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 Park Service, the U.S. Army, the U.S. Marine Corps, the 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, including northern long-eared 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

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Publications

De La Cruz, J.L., Deeley, S., Muthersbaugh, M., Freeze, S.R., Kalen, N., and Silvis, A., 2019, Occupancy and detection probability of northern long-eared bats and other WNS-impacted species in the northeastern United States: Hadley, Mass., U.S. Fish and Wildlife Service, 133 p.

Ford, W.M., Silvis, A., Rodrigue, J.L., Kniowski, A.B., and Johnson, J.B., 2016, Deriving habitat models for northern long-eared bats from historical detection data—A case study using the Fernow Experimental Forest: Journal of Fish and Wildlife Management, v. 7, no. 1, p. 86–98, https://doi.org/10.3996/012015-jfwm-004.

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Reynolds, R.J., Powers, K.E., Orndorff, W., Ford, W.M., and Hobson, C.S., 2016, Changes in rates of capture and demographics of *Myotis septentrionalis* (northern long-eared bat) in western Virginia before and after onset of white-nose syndrome: Northeastern Naturalist, v. 23, no. 2, p. 195–204, https://doi.org/10.1656/045.023.0201.

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St. Germain, M.J., Kniowski, A.B., Silvis, A., and Ford, W.M., 2017, Who knew? First *Myotis sodalis* (Indiana bat) maternity colony in the coastal plain of Virginia: Northeastern Naturalist, v. 24, no. 1, p. N5–N10, https://doi.org/10.1656/045.024.0110.

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. Foraging habitat suitability is being related to bat occurrence, the frequency of feeding events, and insect abundance by 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. Scientists also tested the utility of genetic markers to identify the sex of Hawaiian hoary bats. Using this method for sexing of these bats can permit reliable evaluation of the ratio of males to females in subpopulations affected by emerging threats, including timber harvest practices, entanglement on barbed-wire fencing, exposure to pesticides, and fatal collisions with wind turbines.

Contact

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Publications

Gorresen, P.M., Brinck, K.W., DeLisle, M.A., Montoya-Aiona, K., Pinzari, C.A., and Bonaccorso, F.J., 2018, Multi-state occupancy models of foraging habitat use by the Hawaiian hoary bat (*Lasiurus cinereus semotus*): PLOS ONE, v. 13, no. 10, e0205150, 14 p., https://doi.org/10.1371/journal.pone.0205150.

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Photograph by Frank Bonaccorso, U.S. Geological Survey.

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

Left: An endangered Hawaiian hoary bat. Right: Coastal dunes of the Ki‘i Unit in James Campbell National Wildlife Refuge on O‘ahu, Hawai‘i.

8. Bat Monitoring in the North Coast and Cascades Network of National Parks

Due to a recent detection of WNS, a deadly bat fungal disease, in Washington State, the NPS is interested in the status and distribution of bats within the North Coast and Cascades Network of National Parks. USGS scientists are designing and evaluating bat sampling protocols for Mount Rainier, Olympic, and North Cascades National Parks that are compatible with NABat protocols. They are also developing a protocol to better understand the phenology of acoustic detections from low to high elevations. The new study provides baseline occupancy and distribution information and contributes to local, regional, and rangewide knowledge on the status and trends of multiple bat species, including at least two candidate species for State listing as threatened or endangered, Keen's myotis and Townsend's big-eared bat.

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9. Distribution of Bat Species in Relation to Habitat Characteristics in Marin County, California

USGS scientists have partnered with the NPS, the USFWS, California State Parks, Marin County Parks, and the Marin Municipal Water District to conduct a multispecies occupancy study across lands managed by four open-space agencies in Marin County, California, where 13 bat species potentially occur. The study will assess how bat species distributions are affected by landscape-level and microhabitat features that operate on many scales. Understanding the habitat characteristics that drive bat species richness or restrict habitat suitability for certain species may provide for opportunities to improve habitat management for bats.

Contact

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Bat Behavior Near Wind Turbines and Strategies to Minimize Adverse Impacts

10. Using Genomics to Determine History and Trends of a Bat Population Susceptible to Wind Turbines

The hoary bat is a migratory species, seasonally moving hundreds of miles and ranging throughout most parts of the United States and Canada. Due to the cryptic nature of hoary bats and their disproportionately high mortality at wind energy facilities, there is uncertainty regarding the population status of the species. USGS researchers have partnered with the USFWS to investigate population history and trends of hoary bats in North America by using genomic techniques to provide useful information to resource managers tasked with assessing the impacts of wind energy development on current populations of the species. Specifically, the USGS is sequencing the genomes of hoary bats found dead at wind turbines over a timespan of about 10 years to test for indications of population change by comparing the genomes of turbine fatalities gathered in recent years to those gathered in the previous decade. In addition, studies will estimate historical sizes of hoary bat populations, spanning from approximately 10,000 to over 1 million years before present, to determine how big (or small) the population has ever been, as well as how quickly the population has changed over time. New genetic methods for estimating population trends can assist conservation managers in management of bats facing potential population declines and could be applied toward recovery of endangered bat species, such as the Indiana bat.

Contact

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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.

11. Bat Behavior and Fatalities at Wind Energy Facilities

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.

A hoary bat found dead beneath a wind turbine. Photograph by Paul Cryan, U.S. Geological Survey.

Contact

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Publications

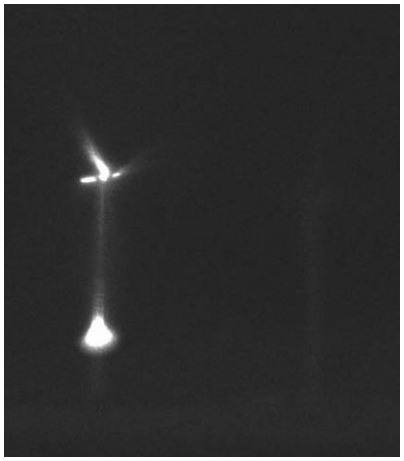
Hayman, D.T.S., Cryan, P.M., Fricker, P.D., and Dannemiller, N.G., 2017, Long-term video surveillance and automated analyses reveal arousal patterns in groups of hibernating bats: Methods in Ecology and Evolution, v. 8, no. 12, p. 1813–1821, https://doi.org/10.1111/2041-210X.12823.

O'Shea, T.J., Cryan, P.M., and Bogan, M.A., 2018, United States bat species of concern–A synthesis: Proceedings of the California Academy of Sciences, v. 65, supplement 1, p. 1–279, https://pubs.er.usgs.gov/publication/70200786.

O'Shea, T.J., Cryan, P.M., Hayman, D.T.S., Plowright, R.K., and Streicker, D.G., 2016, Multiple mortality events in bats—A global review: Mammal Review, v. 46, no. 3, p. 175–190, https://doi.org/10.1111/mam.12064.

12. 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 and testing 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 on refining a selectively perceptible wind turbine system to prevent bat fatalities. This project is testing whether dim, flickering, and position-shifting ultraviolet (UV) light can deter bats from approaching turbines. Results from this and related research could 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.



A wind turbine is dimly lit with flickering ultraviolet (UV) light and imaged by using a video camera sensitive to UV light. Image from video clip by Paul Cryan, U.S. Geological Survey.

Contact

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Publications

Cryan, P.M., Dalton, D.C., and Gorresen, P.M., 2018, Selectively perceptible wind turbine system: U.S. Patent no. US 20160169501 A1, 8 p., https://patentimages.storage.googleapis.com/ab/51/7c/1806ca0421d3ac/US9995282.pdf.

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Gorresen, P.M., Cryan, P.M., Dalton, D.C., Wolf, S., Johnson, J.A., Todd, C.M., and Bonaccorso, F.J., 2015, Dim ultraviolet light as a means of deterring activity by the Hawaiian hoary bat *Lasiurus cinereus semotus*: Endangered Species Research, v. 28, no. 3, p. 249–257, https://doi.org/10.3354/esr00694.

13. 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

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Publications

Haefele, M.A., Loomis, J.B., Merideth, R., Lien, A., Semmens, D.J., Dubovsky, J., Wiederholt, R., Thogmartin, W.E., Huang, T.-K., McCracken, G., Medellin, R.A., Diffendorfer, J.E., and López-Hoffman, L., 2018, Willingness to pay for conservation of transborder migratory species—A case study of the Mexican free-tailed bat in the United States and Mexico: Environmental Management, v. 62, no. 2, p. 229–240, https://doi.org/10.1007/s00267-018-1046-1.

López-Hoffman, L., Diffendorfer, J., Wiederholt, R., Bagstad, K.J., Thogmartin, W.E., McCracken, G., Medellin, R.L., Russell, A., and Semmens, D.J., 2017, Operationalizing the telecoupling framework for migratory species using the spatial subsidies approach to examine ecosystem services provided by Mexican free-tailed bats: Ecology and Society, v. 22, no. 4, 8 p., https://doi.org/10.5751/ES-09589-220423.

14. 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.

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15. 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.

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Additional Publications

Gorresen, P.M., Cryan, P.M., Montoya-Aiona, K., and Bonaccorso, F.J., 2017, Do you hear what I see? Vocalization relative to visual detection rates of Hawaiian hoary bats (*Lasiurus cinereus semotus*): Ecology and Evolution, v. 7, no. 17, p. 6669–6679, https://doi.org/10.1002/ece3.3196.

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Raptors and Land-Based Wind Energy

Raptors are susceptible to collisions with wind turbines, and populations may also be at risk from other anthropogenic hazards, such as electrocution and poisoning (Watson and others, 2018). USGS scientists study raptor ecology, movement, distribution, and habitat requirements and are advancing Global Positioning System (GPS) telemetry techniques to improve estimation of flight altitude and further refine models of golden eagle and California condor flight behavior over landscapes that are amenable to wind energy development. These efforts and other research on novel monitoring methods to study raptor breeding, survival, fatalities, and potential mitigation strategies can assist State and Federal land managers in managing raptor populations and the energy industry in siting projects to minimize potential risks to these species.

Image from video clip by Stephen M. Wessells, U.S. Geological Survey.

Mojave golden eagle.

16. 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, California, New Mexico, the Mojave and Sonoran Deserts, and starting in 2019, Yellowstone National Park. Researchers are 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. Data are used to model movement, resource use, and environmental drivers associated with reproduction and survival. Data are also used to create risk models to assist resource management agencies in evaluating management options for golden eagles. 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 by U.S. Geological Survey.

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At left: Golden eagle with a GPS backpack.

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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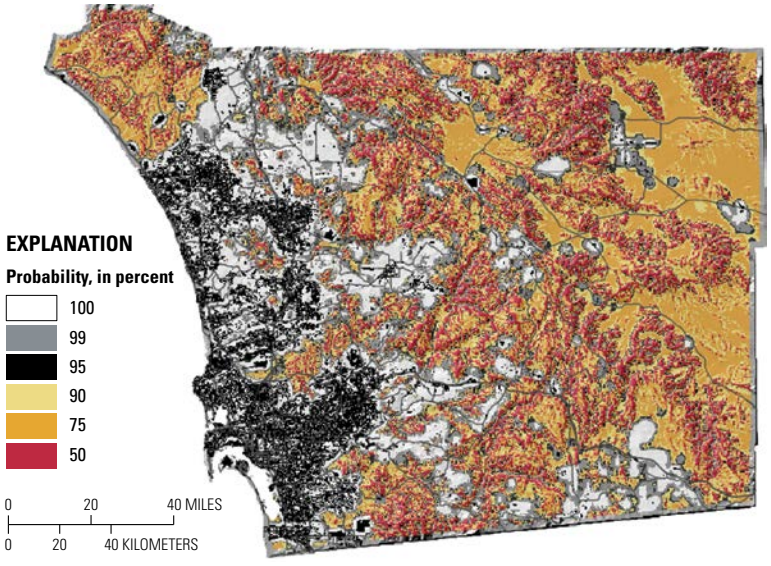
Sur, M., Duerr, A.E., Bell, D.A., Fisher, R.N., Tracey, J.A., Bloom, P.H., Miller, T.A., and Katzner, T.E., 2019, Relevance of individual and environmental drivers of movement of golden eagles: Ibis, accepted article posted August 13, 2019, 51 p., https://doi.org/10.1111/ibi.12766.

Sur, M., Suffredini, T., Wessells, S.M., Bloom, P.H., Lanzone, M., Blackshire, S., Sridhar, S., and Katzner, T., 2017, Improved supervised classification of accelerometry data to distinguish behaviors of soaring birds: PLOS ONE, v. 12, no. 4, e0174785, 19 p., https://doi.org/10.1371/journal.pone.0174785.

17. 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, the 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



Contours of the population-level probabilities of golden eagle habitat selection (modified from Tracey and others, 2018).

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.

Contact

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Publications

Tracey, J.A., Madden, M.C., Bloom, P.H., Katzner, T.E., and Fisher, R.N., 2018, Golden eagle (*Aquila chrysaetos*) habitat selection as a function of land use and terrain, San Diego County, California: U.S. Geological Survey Open-File Report 2018–1067, 13 p., https://doi.org/10.3133/ofr20181067.

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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 or inform repowering (the updating of wind turbines) of existing wind energy sites.

Contact

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Publications

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

Wind turbines at the Altamont Pass wind farm in northern California.

19. 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.

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20. 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.

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Publications

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Photograph from U.S. Fish and Wildlife Service.

California condor.

21. Interactions of Juvenile Swainson's Hawks With Wind Energy Facilities During Dispersal and Migration

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 that all have interests in wind energy development. Development of wind energy facilities in Texas and Argentina along the migration route of Swainson's hawks has raised concerns for potential risks to raptors from direct mortality and habitat loss due to wind facilities. This project, funded by the DOE, can provide survival estimates, movement data, and habitat use data for juvenile Swainson's hawks throughout their migrations. The data can help resource managers better understand and evaluate hemispheric-level risks to this species and similar long-distance migratory birds.

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Publication

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Grassland Birds and Waterbirds and Land-Based Energy

Birds can be indirectly affected by habitat alteration from conventional and renewable energy development (Shaffer and Buhl, 2015), and populations are also at risk from other anthropogenic factors such as grassland conversion to agriculture, environmental contaminants, and climate change. Energy development can degrade habitat quality for breeding birds by introducing noise, movement of large vehicles along new roads, encroachment of invasive plants, and changes in predator populations. USGS scientists are studying the effects of a variety of stressors on breeding birds in the Great Plains, Intermountain West, and other regions of the United States to assist State and Federal land managers in the management of bird populations and the energy industry in siting and managing projects with a better understanding of potential risks to vulnerable bird populations.

Photograph by U.S. Fish and Wildlife Service.

Waterfowl Production Area, Long Lake National Wildlife Refuge in North Dakota.

Northern Prairie and Great Plains

22. 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. 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.

Photograph by Rachel Bush, U.S. Geological Survey.

Male sharp-tailed grouse during spring breeding season.

Additional data were collected by the U.S. Forest Service; the North Dakota Game and Fish Department; South Dakota Game, Fish, and Parks; and Western EcoSystems Technology, Inc. Analyses are being performed to determine correlations between lek parameters (that is, lek densities and mean males per lek) and landscape features.

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23. 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. 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. USGS scientists investigated the effects of proximity to anthropogenic structures on home range and nest placement to better understand the spatial ecology of lesser prairie-chicken and the influences of habitat change on population trends. 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.

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Publications

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24. Estimating Offsets for Avian Displacement Effects of Anthropogenic Activities

Impacts of anthropogenic activity such as energy development can include the displacement of some species of breeding grassland birds and waterfowl. To quantify and compensate for this loss in value of avian breeding habitat, USGS and USFWS scientists developed a method to determine the amount of habitat needed to provide equivalent biological value for avifauna displaced by energy and transportation infrastructure, on the basis of five metrics: impact distance, impact area, pre-impact density, percent displacement, and offset density. Recent studies demonstrated the applicability of the avian-impact offset method, using examples for wind and oil infrastructure. Scientists also developed a worksheet that informs potential users how to apply the method to specific developments and a framework for decision-support tools aimed at achieving landscape-level conservation decisions for biodiversity offsetting. These tools can be applied in situations where compensatory mitigation for impacted habitat is desirable or required.

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Publications

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Photograph by Lawrence D. Igl, U.S. Geological Survey.

Researchers have documented the behavioral avoidance of some species of grassland birds to oil infrastructure, such as to this well pump jack in Fallon County, Montana.

25. Assessing Potential Disturbance and Threats Posed by Energy Development for Aransas-Wood Buffalo Whooping Cranes

Endangered whooping cranes of the Aransas-Wood Buffalo population are encountering increased human activity. The USGS, in partnership with the USFWS, the Canadian Wildlife Service, and Parks Canada, is engaged in studies to determine how three energy extraction activities constitute potential risk for species recovery. Oil and gas extraction has expanded at Aransas National Wildlife Refuge, located in southeast Texas, and potential disturbance and other impacts are not known. Cranes also migrate through Canada's oil sands mining region twice annually, and the consequences of migrating through mining areas have not been determined. Finally, uncertainty persists regarding the potential threat of wind energy infrastructure. Identification and assessment of risk factors can allow development of conservation and management programs targeted to minimize risk for all energy extraction activities.

Photograph by Keith Carver, Creative Commons 2.0 license.

Adult and juvenile whooping cranes, Aransas National Wildlife Refuge, Rockport, Texas.

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26. 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.

Photograph by Steve Gifford, U.S. Fish and Wildlife Service.

Least tern.

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Intermountain West

27. 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 greater 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 greater sage-grouse responses to changing development infrastructure by using a range of expected development intensities and restrictions. Greater sage-grouse responses to climate-induced vegetation changes of future climate scenarios were also simulated to evaluate the influence of climate on greater sage-grouse abundance and distribution. Results indicate that increases in oil and gas development and reduced precipitation could decrease greater sage-grouse abundance and alter distributions through time. Although mean annual changes were small, their accrual through time resulted in discernible population changes, particularly when oil and gas development and climate change occurred together. Results underscore the need to spatially evaluate multiple causes of incremental change to plan landscapes that include human activities and wildlife.

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Publication

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28. 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 greater 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 greater sage-grouse populations.

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Mathews, S.R., Coates, P.S., Prochazka, B.G., Ricca, M.A., Meyerpeter, M.B., Espinosa, S.P., Lisius, S., Gardner, S.C., and Delehanty, D.J., 2018, An integrated population model for greater sage-grouse (*Centrocercus urophasianus*) in the Bi-State Distinct Population Segment, California and Nevada, 2003–17: U.S. Geological Survey Open-File Report 2018–1177, 89 p., https://doi.org/10.3133/ofr20181177.

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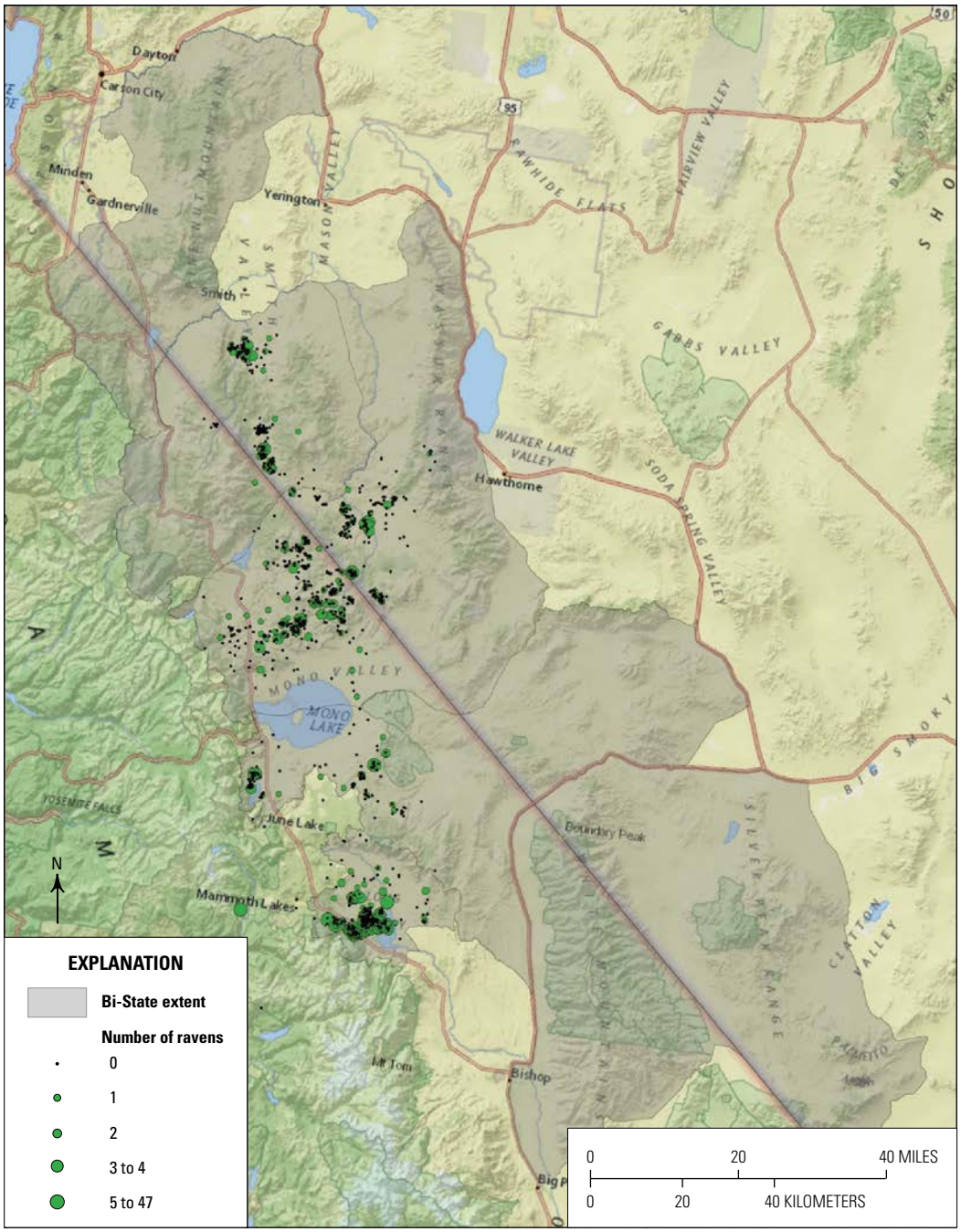

Survey locations and corresponding number of raven detections from March to August across the Bi-State Distinct Population Segment study area, California and Nevada, 2015–17 (modified from Mathews and others, 2018).

29. 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 greater 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

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30. Influence of Energy Development and Climatic Variability on Sagebrush Songbirds

Populations of three species of songbirds (Brewer's sparrow, sagebrush sparrow, sage thrasher) that nest almost exclusively within North American sagebrush habitats have been declining, at least partly due to habitat changes on breeding grounds. The USGS has partnered with the Wyoming Landscape Conservation Initiative (WLCI), the USFWS, the Western Association of Fish and Wildlife Agencies, Wyoming Wildlife Foundation, and the Wyoming Game and Fish Department to evaluate the influence of energy development and a changing climate on species of concern in the sagebrush ecosystem. This project leverages a large, multiyear dataset of sagebrush songbird nests and remotely-sensed weather data to investigate the joint influence of climatic conditions and energy development on the reproductive success of sagebrush songbirds in western Wyoming. Ongoing field efforts continue to document the nesting success of sensitive species in relation to natural gas development and climatic conditions. This information can be used to update Wyoming's Comprehensive Wildlife Conservation Strategy and the Wyoming State Wildlife Action Plan, inform climate vulnerability assessments, and address informational needs of the multiagency Sagebrush Conservation Initiative.

Contact

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Publication

Sanders, L.E., and Chalfoun, A.D., 2019, Mechanisms underlying increased nest predation in natural gas fields—A test of the mesopredator release hypothesis: Ecosphere, v. 10, no. 5, e02738, 17 p., https://doi.org/10.1002/ecs2.2738.

Alaska

Photograph by Randy J. Brown, U.S. Fish and Wildlife Service.

Scientists standing on the shore of the Canning River, Alaska.

31. Distribution and Abundance of Waterbirds on the North Slope of Alaska

USGS and USFWS scientists assessed the distribution, abundance, population trends, and important habitat areas for 20 waterbird species breeding on the Arctic Coastal Plain, Alaska, including portions of the National Petroleum Reserve–Alaska (NPR–A) and the Arctic National Wildlife Refuge, 1002 area. The authors reanalyzed USFWS aerial survey data collected from 1992 to 2016 to estimate and map population densities, trends, and important habitat areas for waterbird species across the study area. Fine-resolution maps were produced to assist managers tasked with leasing land for oil and gas exploration and researchers looking to explore mechanisms underlying areas of population change.

Contact

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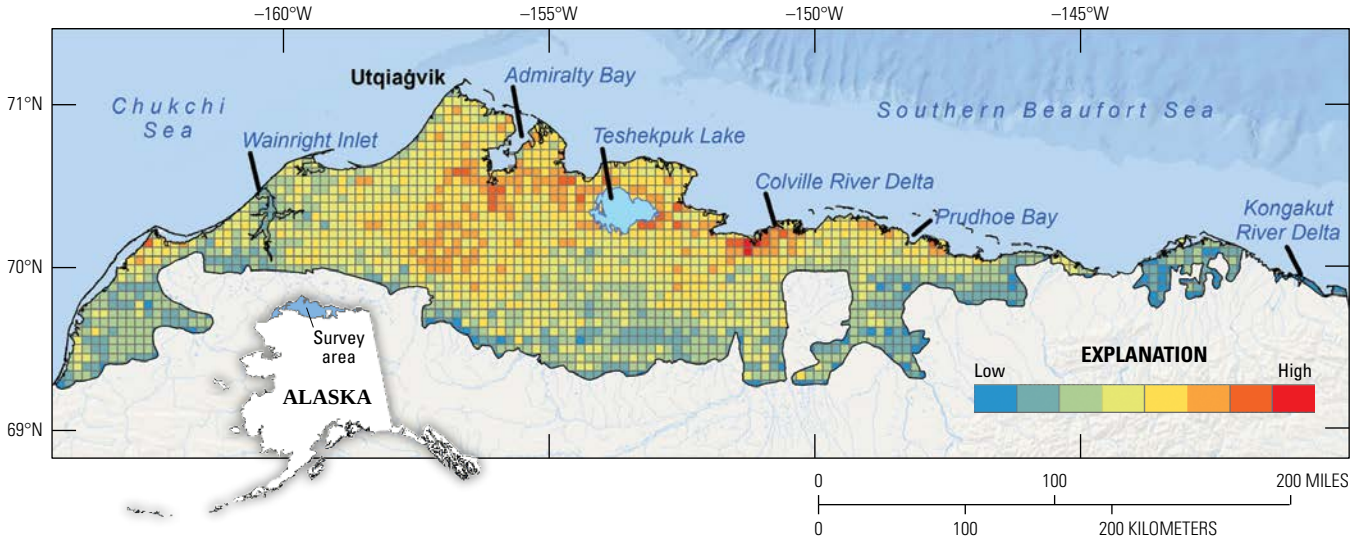
Publication

Amundson, C.L., Flint, P.L., Stehn, R.A., Platte, R.M., Wilson, H.M., Larned, W.W., and Fischer, J.B., 2019, Spatio-temporal population change of Arctic-breeding waterbirds on the Arctic Coastal Plain of Alaska: Avian Conservation and Ecology: v. 14, no. 1, article no. 18, 19 p., https://doi.org/10.5751/ACE-01383-140118.



Relative importance of 36-square-kilometer cells to 20 waterbird species observed during the Arctic Coastal Plain Breeding Waterfowl Survey, Alaska, 1992–2016. Image modified from Amundson and others (2019), Creative Commons 4.0 license.

32. Movement and Habitat Use of Loons on the North Slope of Alaska

The distribution, abundance, and nesting locations of three loon species that breed on the North Slope of Alaska are being studied in relation to future expansion of oil and gas leasing and development in onshore and offshore areas in the region. Management guidelines within the NPR–A exist to protect breeding and foraging areas of yellow-billed loons due to their small population size in the Arctic, but there are no such guidelines for two other species—red-throated loons and Pacific loons—because of limited information on their habitat use patterns. USGS scientists are using multiple years of satellite telemetry data to compare differences in the habitat use of these three loon species on the North Slope and to evaluate the extent to which current oil and gas management guidelines for yellow-billed loons correspond with movements of all three loon species in the NPR–A. This project can inform the BLM, BOEM, and industry of habitat areas used by loons and if breeding territories match current management guidelines for restricted industrial development within certain buffer zones around nesting areas.

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

Yellow-billed loon in a small lake on the Arctic Coastal Plain.

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33. 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

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Additional Publications

Greater Sage-Grouse

Carter, S.K., Manier, D.J., Arkle, R.S., Johnston, A.N., Phillips, S.L., Hanser, S.E., and Bowen, Z.H., 2018, Annotated bibliography of scientific research on greater sage-grouse published since January 2015: U.S. Geological Survey Open-File Report 2018–1008, 183 p., https://doi.org/10.3133/ofr20181008.

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Mahoney, A., and Chalfoun, A.D., 2016, Reproductive success of horned lark and McCown's longspur in relation to wind energy infrastructure: The Condor, v. 118, no. 2, p. 360–375, https://doi.org/10.1650/condor-15-25.1.

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Pollinators and Bioenergy

Conversion of grassland to cropland for biofuel production is replacing pollinator habitat with monoculture crops that have little nutritional value to bees and other native pollinators, thereby reducing forage quality of the landscape (Hellerstein and others, 2017). USGS scientists are assessing land-use changes in relation to intensification of biofuel feedstock production to better understand impacts to pollinator health, diversity, and pollination services in agricultural landscapes. Research efforts include developing conservation seed mixes and decision support tools for improving pollinator conservation.

Photograph from U.S. Geological Survey.

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

34. Using Drones and Citizen Science to Map the Distribution of Milkweed for Monarch Butterflies

Agricultural intensification and the use of glyphosate-resistant crop varieties have contributed to the loss of milkweed in agricultural areas, including the bioenergy crop fields of the upper Midwest. The disappearance of milkweed, the essential host plant for monarch larva, has been implicated in the decline of the monarch butterfly, which was proposed for listing under the Endangered Species Act in 2014. In 2019, USGS scientists partnered with the Monarch Joint Venture to use unmanned aerial vehicles and machine learning software to census the distribution of milkweed on public and private lands in the upper Midwest. This work can inform the design of 21st century monitoring programs for at-risk species and other natural resources.

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Photograph by Savannah Adams, U.S. Geological Survey.

Photograph by Dustin Toy, U.S. Geological Survey.

Left: Monarch caterpillar on milkweed in North Dakota. Right: Unmanned aerial systems (UAS) are being used by U.S. Geological Survey scientists to quantify the distribution of milkweed, a critical resource for monarch butterflies, in North Dakota and Minnesota.

35. 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.

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Publications

Durant, J.L., and Otto, C.R.V., 2019, Feeling the sting? Addressing land-use changes can mitigate bee declines: Land Use Policy, v. 87, article no. 104005, 8 p., https://doi.org/10.1016/j.landusepol.2019.05.024.

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Otto, C.R., Roth, C.L., Carlson, B.L., and Smart, M.D., 2016, Land-use change reduces habitat suitability for supporting managed honey bee colonies in the northern Great Plains: Proceedings of the National Academy of Sciences, v. 113, no. 37, p. 10430–10435, https://doi.org/10.1073/pnas.1603481113.

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Smart, M., Otto, C., Cornman, R., and Iwanowicz, D., 2018, Using colony monitoring devices to evaluate the impacts of land use and nutritional value of forage on honey bee health: Agriculture, v. 8, no. 1, 14 p., https://doi.org/10.3390/agriculture8010002.

Smart, M.D., Otto, C.R.V., Carlson, B.L., and Roth, C.L., 2018, The influence of spatiotemporally decoupled land use on honey bee colony health and pollination service delivery: Environmental Research Letters, v. 13, no. 8, 11 p., https://doi.org/10.1088/1748-9326/aad4eb.

Spivak, M., Browning, Z., Goblirsch, M., Lee, K., Otto, C., Smart, M., and Wu-Smart, J., 2017, Why does bee health matter? The science surrounding honey bee health concerns and what we can do about it: The Council of Agricultural Science and Technology [CAST], CAST Commentary, QTA2017, June, http://www.cast-science.org/publications/?why_does_bee_health_matter_the_science_surrounding_honey_bee_health_concerns_and_what_we_can_do_about_it&show=product&productID=284638.

U.S. Geological Survey, 2016, USGS pollinator research and monitoring [Kirk Mason, producer; Clint Otto, videographer]: U.S. Geological Survey video, 00:05:02, https://www.youtube.com/watch?v=3_O6RDdrfDc.

36. 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 honey bee forage in agroecosystems. They are also modeling historic forage patterns of the federally endangered rusty patched bumble bee on the basis of pollen collected from pinned museum specimens. In 2019, USGS scientists collected pollen from 95 rusty patched bumble bee museum specimens captured between 1923 and 2013 in States ranging from Minnesota to Massachusetts. The deoxyribonucleic acid (DNA) fragments from these pollen samples are currently being identified. Results generated from this project can be used to evaluate specific plants that can be included in conservation and restoration programs for pollinators. Partners in this research include the USDA, the USFWS, and the Keystone Institute.

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Publications

Cornman, R.S., Otto, C.R.V., Iwanowicz, D., and Pettis, J.S., 2015, Taxonomic characterization of honey bee (*Apis mellifera*) pollen foraging based on non-overlapping paired-end sequencing of nuclear ribosomal loci: PLOS ONE, v. 10, no. 12, e0145365, 26 p., https://doi.org/10.1371/journal.pone.0145365.

Smart, M.D., Cornman, R.S., Iwanowicz, D.D., McDermott-Kubeczko, M., Pettis, J.S., Spivak, M.S., and Otto, C.R.V., 2017, A comparison of honey bee-collected pollen from working agricultural lands using light microscopy and ITS metabarcoding: Environmental Entomology, v. 46, no. 1, p. 38–49, https://doi.org/10.1093/ee/nvw159.

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

U.S. Geological Survey scientists are removing and identifying pollen from rusty patched bumble bee museum specimens to describe the historic floral diets of this endangered species.

37. 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.

Photograph by Sarah Scott, under contract to the U.S. Geological Survey.

A native bee rests on woolly paperflower.

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Publications

Iovanna, R., Ando, A., Swinton, S., Kagan, J., Hellerstein, D., Mushet, D., and Otto, C., 2017, Assessing pollinator habitat services to optimize conservation programs, chap. 1 *of* The Council on Food, Agricultural and Resource Economics (C–FARE) Report: Washington, D.C., C–FARE, report no. 0114–301b, 28 p., http://www.cfare.org/youtube-videos/2017/8/30/ysgngrouizyu4mie6647rcblm6jnj6.

Otto, C.R.V., 2019, Assessing the impact of the Conservation Reserve Program on honey bee health: U.S. Geological Survey Fact Sheet 2018–3082, 2 p., https://doi.org/10.3133/fs20183082.

Otto, C.R.V., O'Dell, S., Bryant, R.B., Euliss, N.H., Jr., Bush, R.M., and Smart, M.D., 2017, Using publicly available data to quantify plant-pollinator interactions and evaluate conservation seeding mixes in the northern Great Plains: Environmental Entomology, v. 46, no. 3, p. 565–578, https://doi.org/10.1093/ee/nvx070.

Reptiles and Amphibians and Land-Based Energy

Conventional and renewable energy projects are adding stressors to reptile and amphibian populations experiencing population declines across the United States and worldwide (Adams and others, 2013; Lovich and others, 2018). The USFWS lists 30 species of amphibians and 32 species of reptiles as threatened or endangered in the United States. In addition, dozens of amphibian and reptile species are considered at risk. To address declines in amphibian populations, the USGS formed the Amphibian Research and Monitoring Initiative (ARMI) to study the life history traits of amphibians, measure and monitor environmental characteristics, and research potential causes of decline. Scientists are assessing the effects of land-use change from oil and gas development, wind and solar energy development, and power lines and geothermal power plants, in addition to other stressors, to better understand impacts of energy infrastructure on these sensitive species.

Photograph by Todd C. Esque, U.S. Geological Survey.

Male desert tortoise.

38. Desert Tortoise Recovery 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 wind and solar energy facility impacts to desert tortoise to better understand the behavior responses of this endangered species. Researchers are also studying desert tortoise habitat, including vegetation of the Mojave and Sonoran Deserts, disease prevalence, and tortoise shelter choices in support of wildlife and land management decisions regarding site selection for tortoise translocations.

Contacts

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Jeffrey Lovich, USGS Southwest Biological Science Center, jeffrey_lovich@usgs.gov, (928) 556–7358

Publications

Abella, S.R., and Berry, K.H., 2016, Enhancing and restoring habitat for the desert tortoise: Journal of Fish and Wildlife Management, v. 7, no. 1, p. 255–279, https://doi.org/10.3996/052015-JFWM-046.

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Sánchez-Ramírez, S., Rico, Y., Berry, K.H., Edwards, T., Karl, A.E., Henen, B.T., and Murphy, R.W., 2018, Landscape limits gene flow and drives population structure in Agassiz's desert tortoise (*Gopherus agassizii*): Scientific Reports, v. 8, article no. 11231, 17 p., https://doi.org/10.1038/s41598-018-29395-6.

39. 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, some of which are in areas that may be suitable for geothermal and other energy development. In 2018, the USGS, in collaboration with the BLM, USFWS, Department of Defense, and Nevada Department of Wildlife, developed a research and monitoring program designed to better understand the ecology of narrowly endemic toads in the Great Basin. Initial results suggest that Dixie Valley toads are selective with regard to water temperature, with adults selecting cooler temperatures than tadpoles. This ecological trait could indicate sensitivity to changes in the hydrothermal system supporting the toad's habitat. Ongoing research on the distribution of the toads, the spatiotemporal availability of preferred water temperatures, and toad habitat selection can further inform management of Dixie Valley toads.

Contact

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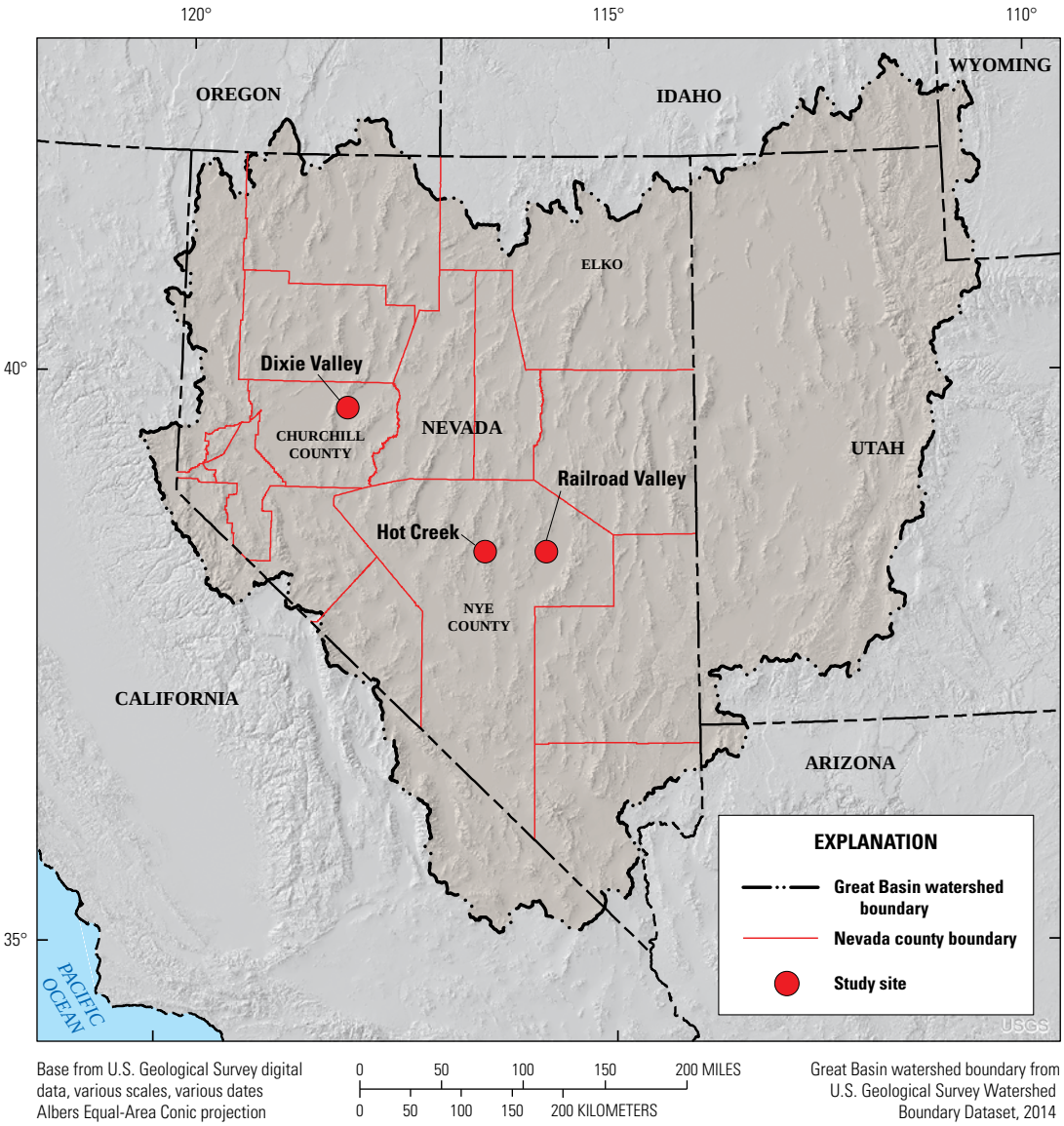
Publication

Halstead, B.J., Kleeman, P.M., Duarte, A., Rose, J.P., Urquhart, K., Mellison, C., Guadalupe, K., Cota, M., Van Horne, R., Killion, A., and Ruehling, K., 2019, Monitoring protocol development and assessment for narrowly endemic toads in Nevada, 2018: U.S. Geological Survey Open-File Report 2019–1067, 28 p., https://doi.org/10.3133/ofr20191067.

Photograph by Kelsey Ruehling, U.S. Geological Survey.

Dixie Valley toad.



Location of the Great Basin watershed in the Western United States. Study sites are indicated with circles; counties in which research was conducted are labeled (modified from Halstead and others, 2019).

40. Effects of Brine Contamination on Amphibians

USGS scientists are examining how saline wastewaters (brines) co-produced during legacy oil extraction in the Williston Basin in the northern Great Plains affect wetlands and amphibians. Field studies found that the abundance of frog larvae in wetlands was sensitive to levels of brine contamination. Notably, water quality and amphibian abundance were more strongly related to presence of nearby oil wells installed before 1982 than to wells installed since 1982, when changes to brine disposal practices reduced the incidence and extent of environmental contamination. Scientists also examined concentrations of 15 metals in sediments and amphibian tissues and found that metal concentrations were less strongly associated with brine contamination of wetlands than expected. Elevated levels of only sodium and strontium were found in sediments, and elevated levels of only selenium and vanadium were found in amphibian tissues. Counter to expectations, grazing benthic tadpoles had higher metal concentrations than predatory salamanders that spend less time in contact with sediment. Improved brine disposal practices are reducing exposure of amphibians to metals in wetland sediments.

Contact

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Publications

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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Smalling, K.L., Anderson, C.W., Honeycutt, R.K., Cozzarelli, I.M., Preston, T., and Hossack, B., 2019, Associations between environmental pollutants and larval amphibians in wetlands contaminated by energy-related brines are potentially mediated by feeding traits: Environmental Pollution, v. 248, p. 260–268, https://doi.org/10.1016/j.envpol.2019.02.033.

Additional Publications

Desert Tortoise

Agha, M., Lovich, J.E., Ennen, J.R., Augustine, B., Arundel, T.R., Murphy, M.O., Meyer-Wilkins, K., Bjurlin, C., Delaney, D., Briggs, J., Austin, M., Madrak, S.V., and Price, S.J., 2015, Turbines and terrestrial vertebrates—Variation in tortoise survivorship between a wind energy facility and an adjacent undisturbed wildland area in the desert Southwest (U.S.A.): Environmental Management, v. 56, no. 2, p. 332–341, https://doi.org/10.1007/s00267-015-0498-9.

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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Ennen, J.R., Lovich, J.E., Averill-Murray, R.C., Yackulic, C.B., Agha, M., Loughran, C., Tennant, L., and Sinervo, B., 2017, The evolution of different maternal investment strategies in two closely related desert vertebrates: Ecology and Evolution, v. 7, no. 9, p. 3177–3189, https://doi.org/10.1002/ece3.2838.

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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.

Lovich, J.E., and Ennen., J.R., 2017, Reptiles and amphibians, chap. 6 *of* Perrow, M.R., ed., Wildlife and windfarms, conflicts and solutions, v. 1, Onshore—Potential effects: Exeter, England, Pelagic, p. 97–118.

Amphibians

Sweeten, S.E., and Ford, W.M., 2016, Effects of microhabitat and large-scale land use on stream salamander occupancy in the coalfields of central Appalachia: Journal of Ecology and the Natural Environment, v. 8, no. 9, p. 129–141, https://doi.org/10.5897/JENE2016.0564.

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Big Game and Other Terrestrial Mammals and Land-Based Energy

Landscape fragmentation due to oil and gas energy development, wind facilities, and associated service roads can affect seasonal migration, reproduction, and survival of big game species such as mule deer, pronghorn antelope, elk, and other terrestrial mammals (Wyckoff and others, 2018). Creation of barriers along migration routes and altered predator communities may also present new stressors. USGS scientists assist State and Federal resource and land management agencies such as the BLM and USFWS in evaluating the potential effects of energy facility expansion and energy production activities by studying big game migration corridors and behavior relative to anthropogenic disturbance. Research efforts are also focused on identifying strategies that can minimize adverse impacts to these species.

Photograph by Jonny Armstrong, U.S. Geological Survey.

Elk traveling on winter range in the northwestern Greater Yellowstone Ecosystem after crossing the Madison River near Ennis, Montana.

41. 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

Photograph by Steve Hillebrand, U.S. Fish and Wildlife Service.

Adult pronghorn.

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

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Publications

Aikens, E.O., Kauffman, M.J., Merkle, J.A., Dwinnell, S.P.H., Fralick, G.L., and Monteith, K.L., 2017, The greenscape shapes surfing of resource waves in a large migratory herbivore: Ecology Letters, v. 20, no. 6, p. 741–750, https://doi.org/10.1111/ele.12772.

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Merkle, J.A., Monteith, K.L., Aikens, E.O., Hayes, M.M., Hersey, K.R., Middleton, A.D., Oates, B.A., Sawyer, H., Scurlock, B.M., and Kauffman, M.J., 2016, Large herbivores surf waves of green-up during spring: Proceedings of the Royal Society B—Biological Sciences, v. 283, no. 1833, 8 p., https://doi.org/10.1098/rspb.2016.0456.

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Wyckoff, T.B., Sawyer, H., Albeke, S.E., Garman, S.L., and Kauffman, M.J., 2018, Evaluating the influence of energy and residential development on the migratory behavior of mule deer: Ecosphere, v. 9, no. 2, e02113, 13 p., https://doi.org/10.1002/ecs2.2113.

42. Pronghorn Responses to Wind Farms

In Wyoming, new wind farms are planned for construction within critical winter range for pronghorn, but little is known about pronghorn responses to wind energy infrastructure and operations. In collaboration with the WLCI, USGS scientists are evaluating changes in movement and habitat use of pronghorn tracked with GPS collars from before construction of two wind farms (construction began in spring 2019) to several years after construction. This analysis includes an assessment of the long-term effects of wind farms on pronghorn through comparisons of recent habitat use within an existing wind farm to movement data collected during and after construction of the wind farm from 2010 to 2012. Results can inform land and wildlife managers of risks for pronghorn associated with further development of wind energy that is expected in this region.

Photograph by Neal Herbert, National Park Service.

North American pronghorn.

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43. Influence of Oil Development on the Behavior of Barren-Ground Caribou

Interest in oil and gas production on the North Slope of Alaska is raising questions about the resilience of barren-ground caribou populations to new development. Although the amount of habitat lost directly to energy development in the Arctic will likely be small in relation to the total area, there are significant concerns about indirect effects such as avoidance behaviors by caribou. To understand the long-term effects of energy development on barren-ground caribou, USGS scientists are investigating the behavior of the Central Arctic Herd, which has been exposed to oil development on its summer range for approximately 40 years. Using recent (2015–2017) location data from GPS-collared females, scientists are conducting a zone of influence analysis to assess whether caribou reduce their use of habitat near energy development, and if so, the distance at which the effects attenuate. Analyses include periods of calving and post-calving and mosquito periods when caribou exhibit distinct resource selection patterns. New findings will be compared to past research on the herd that was conducted immediately after the development of the oil fields. Results from this work can be used by Federal land management agencies to better understand the long-term impacts of energy development on caribou behavior.

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

Three caribou standing in the tundra in Alaska.

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44. Measuring the Impacts of Industrial Activities on Polar Bears

USGS scientists are characterizing changes 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 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.

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Publications

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. 11, no. 6, e01370, 22 p., https://doi.org/10.1002/ecs2.1370.

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McKinney, M.A., Atwood, T.C., Pedro, S., and Peacock, E., 2017, Ecological change drives a decline in mercury concentrations in southern Beaufort Sea polar bears: Environmental Science and Technology, v. 51, no. 14, p. 7814–7822, https://doi.org/10.1021/acs.est.7b00812.

45. 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, 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.

Photograph by U.S. Geological Survey.

Polar bear family at a whale bone pile near Kaktovik, Alaska.

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Publications

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, 22 p., https://doi.org/10.1002/ecs2.1370.

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Additional Publications

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Coastal and Marine Birds and Offshore Energy

Oil and gas extraction and related activities in the ocean may impact coastal and marine birds through collisions with infrastructure or exposure to at-sea oil pollution. Offshore wind-generated electricity promises to be an important source of renewable energy but may pose additional risk to coastal and marine birds that share airspace with future offshore wind facilities. USGS scientists assist regulatory agencies such as BOEM and the USFWS in evaluating the potential effects of offshore energy facilities and related activities by studying seabird movement, distribution, and flight and foraging behavior in the coastal and marine environment and by identifying areas of relative high and low overlap between seabird species of conservation concern and proposed offshore facilities.

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

Flock of birds over Arey Island on the coastline of the Beaufort Sea near Kaktovik, Alaska.

Alaska

46. North Pacific Pelagic Seabird Survey

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 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.

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Publications

Drew, G.S., Piatt, J.F., and Renner, M., 2015, User's guide to the North Pacific Pelagic Seabird Database 2.0: U.S. Geological Survey Open-File Report 2015–1123, 52 p., https://doi.org/10.3133/ofr20151123.

Renner, M., Salo, S., Eisner, L.B., Ressler, P.H., Ladd, C., Kuletz, K.J., Santora, J.A., Piatt, J.F., Drew, G.S., and Hunt, G.L., 2016, Timing of ice retreat alters seabird abundances and distributions in the southeast Bering Sea: Biological Letters, v. 12, no. 9, e20160276, 7 p., https://doi.org/10.1098/rsbl.2016.0276.

47. 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.

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

Black-legged Kittiwakes forage on Pacific sand lance and capelin near their colony on Gull Island, Cook Inlet, Alaska.

Atlantic Ocean

48. Satellite Tracking Offshore Habitat Use in Diving Birds

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 their 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.

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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, 260 p., https://pubs.er.usgs.gov/publication/70194432.

49. 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.

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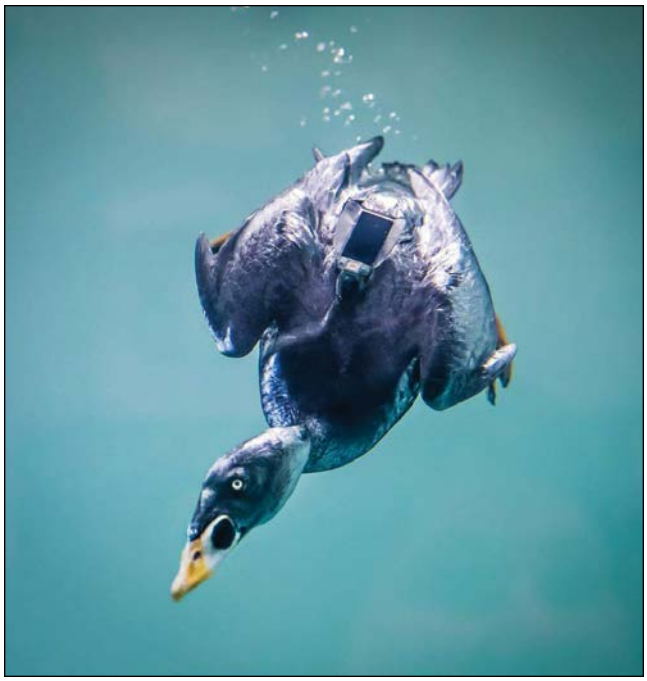

Photograph by Jonathan Fiely, U.S. Geological Survey.

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

50. 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.

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Publications

Althouse, M.A., Cohen, J.B., Karpanty, S.M., Spendelow, J.A., Davis, K.L., Parsons, K.C., and Luttazi, C.F., 2019, Evaluating response distances to develop buffer zones for staging terns: Journal of Wildlife Management, v. 83, no. 2, p. 260–271, https://doi.org/10.1002/jwmg.21594.

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.

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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.

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., 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.

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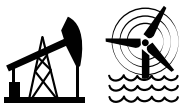

51. Spatial and Foraging Ecology of Brown Pelicans in the South Atlantic Bight

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 northeastern Florida to assess foraging ranges, movement patterns, and migration paths. This research also complements pelican tracking efforts being conducted in the Gulf of Mexico (GOM).

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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.

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The Atlantic Offshore Seabird Dataset Catalog

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Diving Bird Acoustic Sensitivity Studies

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Great Lakes

52. Distribution, Abundance, and Movement of Waterbirds on 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. In addition, satellite telemetry has been used to document movement and habitat use of common loons during migration across the Great Lakes and long-tailed ducks while wintering on 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 resource managers with energy development planning and siting decisions.

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

Red-throated loon.

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Publications

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Gulf of Mexico

53. 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.

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54. 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 at-sea distribution and habitat use of seabirds 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.

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Publications

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Photograph by U.S. Geological Survey.

Brown pelican with chick.

Pacific Ocean

55. 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.

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Publication

Adams, J., Lafferty, K.D., Kelsey, E.C., and Johnston, C.A., 2019, Synopsis of research programs that can provide baseline and monitoring information for offshore energy activities in the Pacific region—Seabird and marine mammal surveys in the Pacific region: Camarillo, Calif., U.S. Department of the Interior, Bureau of Ocean Energy Management, OCS Study BOEM 2019–042, prepared under BOEM Intra-Agency Agreement no. M14PG00039, 54 p., https://www.boem.gov/2019-042/.

56. Southern California Marine Bird and Mammal Surveys

The Southern California Bight and the Pacific OCS biome provide habitat for numerous migratory, resident, and breeding species of seabirds and marine mammals. Multiple wind energy projects have been proposed for this region, which supports important regional populations of several species, including black storm-petrel, brown pelican, Scripps's murrelet, elegant tern, and approximately one-half of the world population of endemic ashy storm-petrels. In partnership with BOEM, the USGS is conducting aerial photographic surveys of the ocean off central and southern California and developing new methods that use machine learning algorithms to detect seabirds and marine mammals in images. Automating detection and counts can allow researchers to generate comprehensive, quantitative data on species composition, distribution, abundance, habitat associations, and seasonal variation of seabirds and marine mammals from imagery. This project builds upon aerial and ship-based observational surveys conducted throughout the Pacific OCS over the past 40 years, and current data will be related to historic data to inform the permitting and planning process for offshore wind development.

Photographs by U.S. Geological Survey.

Photographs captured during an aerial survey showing (left) a California brown pelican and (right) two northern right whale dolphins.

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Publications

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

California, Oregon, and Washington are engaged with BOEM and the National Oceanic and Atmospheric Administration (NOAA) to plan the siting of offshore energy projects within the territorial sea and Pacific OCS regions. The USGS and collaborators are using historic, aerial- and vessel-based, transect survey data coupled with oceanographic and environmental data to develop predictive models of marine bird distributions and relative density. These data can be used to map areas of high or low relative bird abundance throughout a large region of the California Current System, helping Pacific OCS States and BOEM evaluate areas in advance of future energy development.

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58. Main Hawaiian Islands Breeding Seabird Atlas

The main Hawaiian Islands (MHI) and associated offshore areas provide substantial breeding habitat for more than 19 native seabird species that spend the majority of their lives at sea and use these waters for foraging, resting, and commuting. Offshore areas surrounding the MHI have been proposed for wind energy-related projects that 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, colony extents, and breeding population sizes to inform siting, conservation, and mitigation actions for affected species. The 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. The atlas can provide benchmarks to measure future changes in seabird population sizes and breeding distribution and can also assist efforts to evaluate threats to seabirds both on land and at sea.

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59. Main Hawaiian Islands Seabird Tracking

As of January 2017, the State of Hawai‘i’s alternative energy policy mandates and Federal interest in developing offshore renewable energy resources have prompted unsolicited lease requests to BOEM for offshore wind energy infrastructure in ocean waters off Hawai‘i. The MHI support important seabird breeding populations that could be vulnerable to offshore wind energy infrastructure. The USGS assessed at-sea ranging behaviors among seabirds to provide new information on breeding seabird distribution at sea, habitat utilization, and ranging behaviors within near-island waters and throughout OCS waters surrounding the MHI. USGS scientists examined the at-sea distributions and ranging behaviors of five abundant breeding species in the MHI: brown booby, red-footed booby, red-tailed tropicbird, Laysan albatross, and wedge-tailed shearwater. From 2013 to 2016, scientists studied 1,128 breeding individuals of these species from 14 sites throughout the MHI by using GPS loggers and time-depth recorders; study colonies were on the islands of Maui, O‘ahu, Kaua‘i, and associated islets. Data from this study can inform BOEM and State of Hawai‘i decisions regarding offshore wind energy development.

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

A white-tailed tropicbird flying.

60. Seabird and Marine Mammal Aerial Surveys Off Northern California, Oregon, and Washington

During 2011 and 2012, the USGS partnered with BOEM to complete the Pacific Continental Shelf Environmental Assessment (PaCSEA), which included replicated marine bird and mammal surveys from the shore over the continental shelf and slope along 32 broad-scale transects from northern California to Washington State. Additionally, finer scale surveys were conducted over the continental shelf within six designated areas of interest to BOEM: Fort Bragg, California; Eureka, California; Siltcoos Bank, Oregon; Newport, Oregon; Nehalem Bank, Oregon; and Grays Harbor, Washington. Synchronous tracking data were collected for one of the most abundant species in the region, common murre, to evaluate how survey and tracking data can inform marine spatial planning in complementary ways. Tracking data have revealed how the species adjusts its diving behavior when faced with anomalous ocean conditions. These data provide updated distribution, abundance, and behavior information on seabirds and marine mammals for potential offshore renewable energy development in the region.

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Publications

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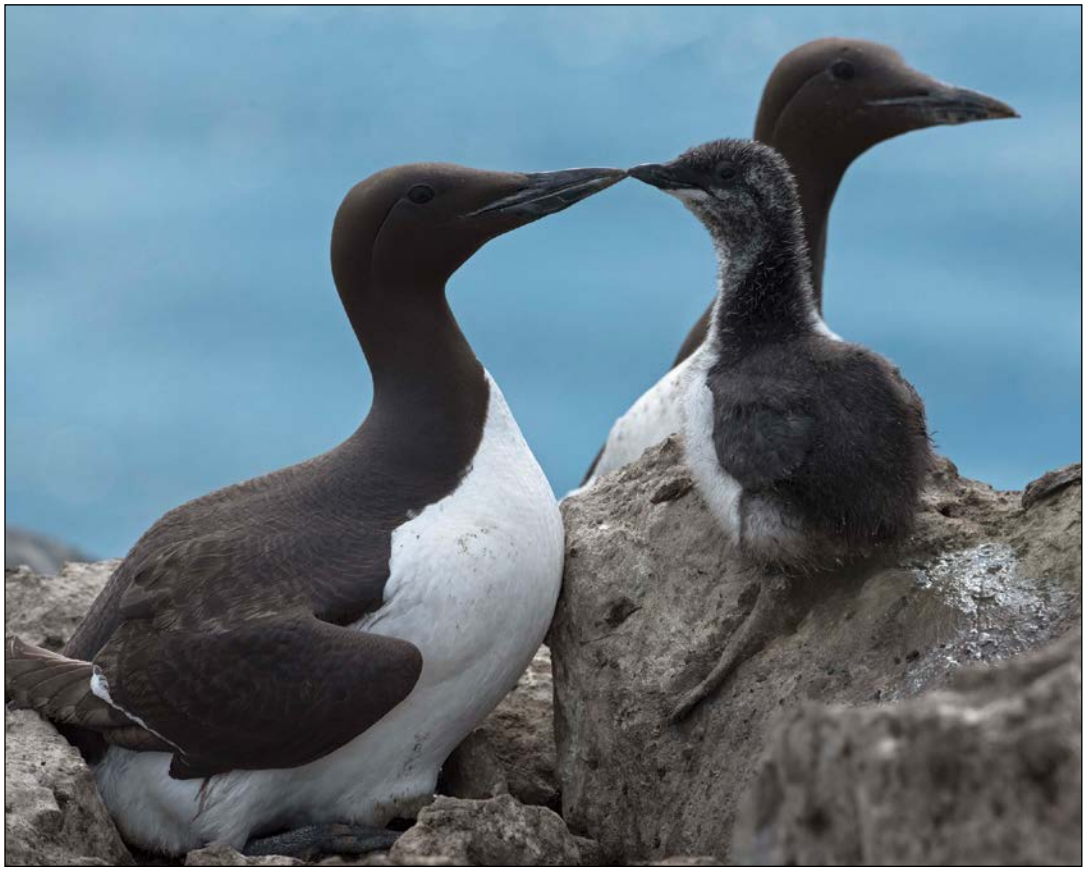

Photograph by Sarah Schoen, U.S. Geological Survey.

Common murres in Cook Inlet, Alaska.

61. Seabird Vulnerability Assessment for Renewable Energy Projects on the Pacific Outer Continental Shelf

In partnership with BOEM, the USGS quantified collision and displacement vulnerability to offshore wind energy development for 81 marine bird species common to the California Current System portion of the Pacific OCS. The vulnerability values generated for these bird species were based on life history traits, population size, demography, habitat use, disturbance sensitivity, and conservation status. The vulnerability values generated in this assessment can be used by resource managers to evaluate potential impacts associated with the construction and long-term operation of offshore wind energy infrastructure.

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Publications

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Marine Animals and Offshore Energy

BOEM is responsible for leasing and development activities in the OCS related to energy and mineral resources and therefore requires baseline information and scientific studies on the effects of industrial activities on biological, environmental, and cultural resources for its leasing and management decisions. USGS scientists support BOEM's environmental science priorities by providing science to help assess, predict, monitor, and manage environmental impacts on marine biota and the human, marine, and coastal environments. In Alaska, USGS scientists are studying the distribution, abundance, and behavior of marine mammals, such as the pacific walrus, and marine and diadromous fish in nearshore systems in relation to offshore industrial activities. In the GOM and Atlantic Ocean, research activities are focused on studying manatees and sea turtles in relation to current and potential energy production and mineral extraction and transportation activities. Seafloor mapping and benthic ecosystem studies in the Atlantic and Pacific OCS regions are characterizing novel cold-water corals and seep-associated ecological communities in the deep sea and can inform BOEM decisions regarding the installation, operation, and structural integrity of proposed renewable energy projects.

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

Pacific walrus hauled out on sea ice in the Chukchi Sea.

Alaska

62. 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.

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Publications

Bodkin, J.L., Coletti, H.A., Ballachey, B.E., Monson, D.H., Esler, D., and Dean, T.A., 2018, Variation in abundance of Pacific blue mussel (*Mytilus trossulus*) in the northern Gulf of Alaska, 2006–2015: Deep Sea Research Part II—Topical Studies in Oceanography, v. 147, p. 87–97, https://doi.org/10.1016/j.dsr2.2017.04.008.

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63. Nearshore Fish Surveys in the Beaufort Sea

Nearshore systems provide habitat to marine and diadromous fish that are critical to subsistence fishing in northern Alaska. Rapid changes in physical habitat attributes (for example, temperature and salinity) across the Arctic have led to species range shifts and have likely modified fish assemblages since baseline studies were conducted in the 1980s and 1990s. In 2017, the USGS initiated a new study to update information on nearshore fish communities along the Beaufort Sea coastline in support of planned development and continued oil and gas production. Study sites include coastal lagoons and exposed coastline near Prudhoe Bay and within the Coastal Plain (that is, the 1002 area) of the Arctic National Wildlife Refuge.

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Photograph by Vanessa von Biela, U.S. Geological Survey.

Biologists identify species, count, and measure length of fish to understand how fish use nearshore habitats in Alaska.

64. 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.

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Publications

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65. 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.

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Atlantic Ocean and Gulf of Mexico

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

The USGS is collecting data related to Florida manatee distribution and their use of habitat and travel corridors in the northern GOM (Florida, Alabama, Mississippi, Louisiana, and Texas). Manatees known to travel to the northern GOM are being captured for health assessments and are tracked with GPS telemetry to acquire fine-scale habitat use and movement information. Field studies focus on characterization of local resources in areas with appropriate habitat or consistent manatee use. The data collected are being used by BOEM to inform the risk of interactions between manatees and vessels traveling through coastal areas to and from offshore oil and gas structures.

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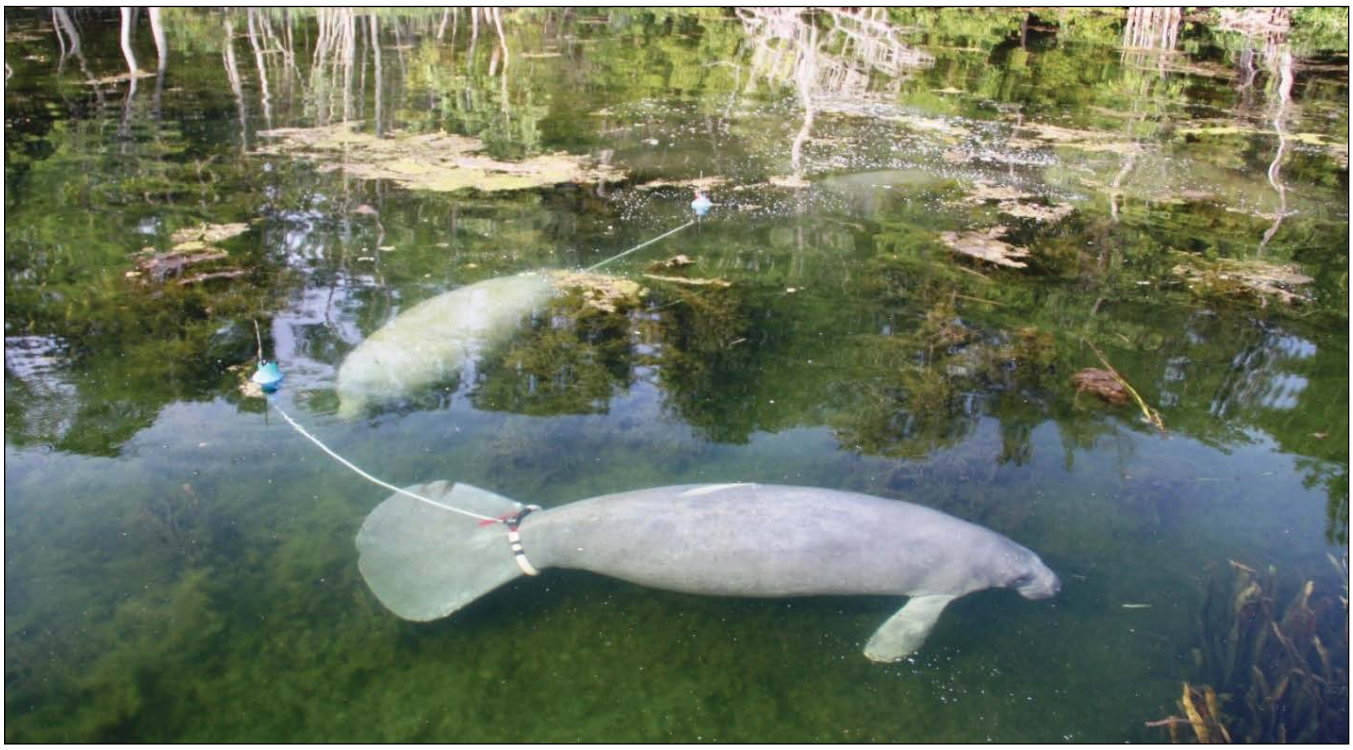

Photograph by Jim Reid, U.S. Geological Survey.

Radio-tagged Florida manatees in the Wakulla River, Florida.

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

In winter, a large segment of the Florida manatee population depends on effluents of heated water produced by coastal thermoelectric power plants. Steam-based electricity generation requires large quantities of water for cooling. The power industry in Florida is transitioning to new technologies that reduce warm-water effluents and working with the USFWS and the Florida Fish and Wildlife Conservation Commission as the agencies develop and implement a manatee warm-water action plan. USGS scientists are developing models based on long-term photographic identification, telemetry, and USGS water studies to predict present and future use of warm-water sites. They are also working with the USFWS to develop decision support tools to identify and evaluate management scenarios and address changing conditions within the network of natural and artificial warm-water sites.

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68. 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 BOEM, the USFWS, NOAA, the National Oceanographic Partnership Program (NOPP), and the 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.

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69. Sea Turtle Movement 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.

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70. Deep-Sea Exploration to Inform Potential Offshore Energy and Minerals Development

The OCS contains extensive and valuable commercial and recreational fisheries, as well as unique deep-sea communities, including corals and chemosynthetic seeps. BOEM, the 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. 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.

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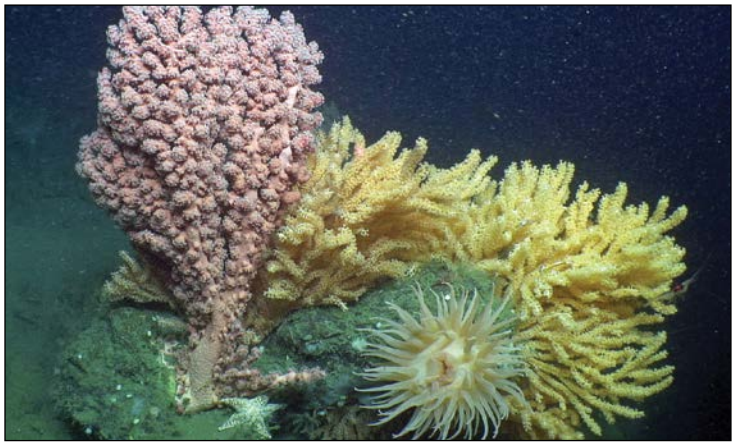
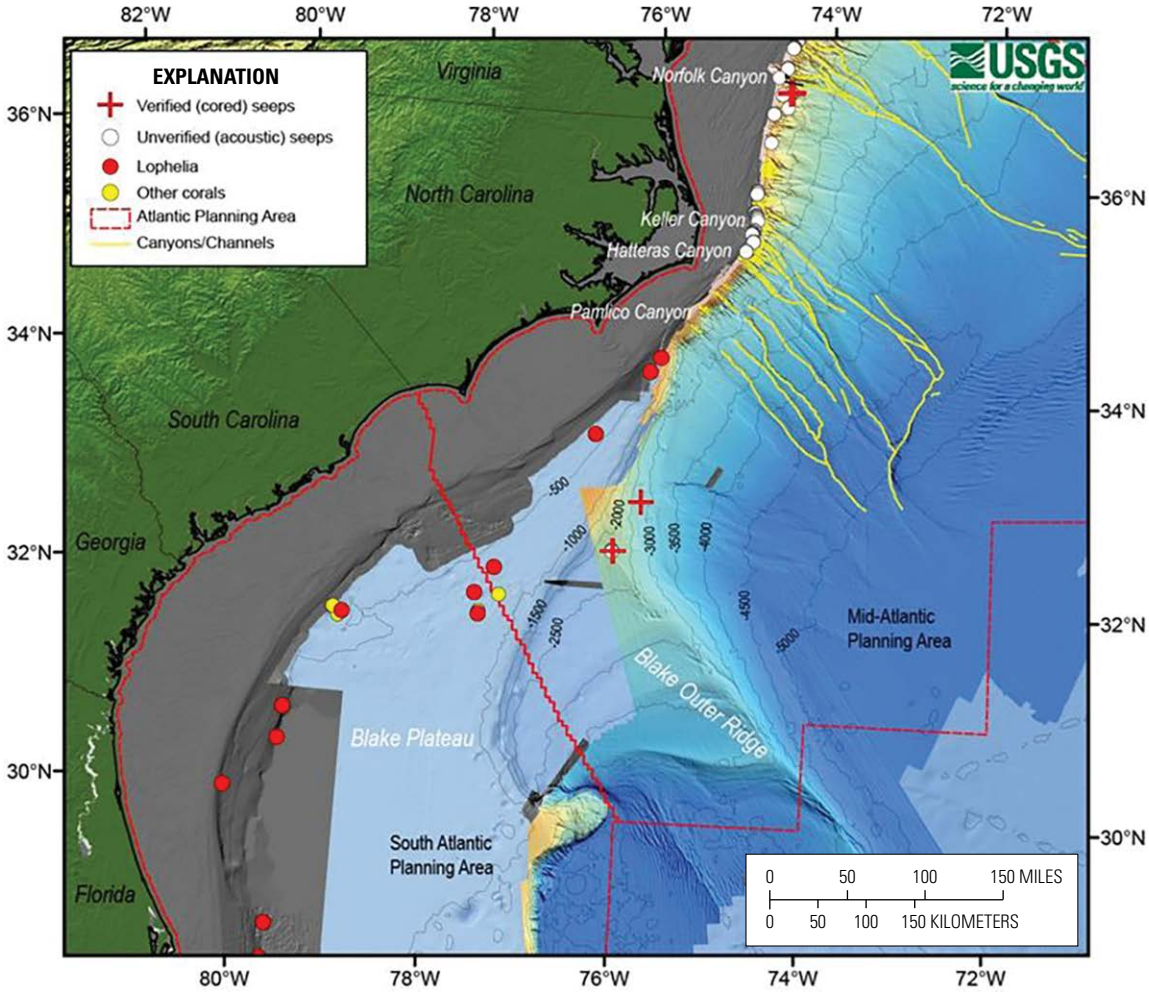


Image courtesy of National Oceanic and Atmospheric Administration.

Red bubblegum coral at a depth of 440 meters in Norfolk Canyon.



Target areas surveyed during the Deepwater Atlantic Habitats II study. Image from U.S. Geological Survey.

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71. 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.

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Pacific Ocean

72. Benthic Assemblages of Mega Epifauna on the Oregon Continental Margin

The USGS partnered with BOEM to map an area of the Oregon OCS under consideration for development of a floating wind energy farm. BOEM requires seafloor mapping and site characterization studies to evaluate the impact of seafloor and sub-seafloor conditions on the installation, operation, and structural integrity of proposed renewable energy projects, as well as to assess the potential effects of construction and operations on benthic ecosystems and archaeological resources. Analysis of video data collected to determine correlations between substrate, depth, and invertebrate assemblages resulted in the identification of seven biomes: three hard-bottom biomes and four soft-bottom biomes. The geologic, topographic, and hydrologic information provided by the USGS support BOEM's mission of responsible management of the Nation's natural resources.

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73. 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.

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Fish and Other Aquatic Species and Hydropower

Hydropower has served as a significant and reliable source of electricity in the United States for more than five decades. One of the main challenges in managing rivers with hydropower resources is maintaining or restoring commercially, recreationally, and culturally important species such as salmon and herring. USGS scientists are applying extensive interdisciplinary capabilities in fish biology, ecology, hydrology, and engineering to improve fish passage designs and ultimately help restore fisheries in managed rivers. USGS scientists are also providing tools for early detection and prevention of invasive species, such as zebra and quagga mussels, which foul hydroelectric facilities and threaten aquatic ecosystems.

Photograph from the Bonneville Power Administration, Creative Commons 2.0 license.

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

Fish Passage and Behavior at Hydropower Dams

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

Many migratory fish species have been in decline 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 fish species. The S.O. Conte Anadromous Fish Research Center laboratory provides semicontrolled conditions that enable the 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. In collaboration with the University of Massachusetts, USGS scientists are testing new fishway attraction and entrance technology designed to enhance fish passage with broad applicability to many target species, including Atlantic salmon, American shad, alewife, and blueback herring. 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.

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75. 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.

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76. 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. Threatened populations of Chinook salmon and steelhead are a primary focus for regional resource managers in the Pacific Northwest. USGS scientists monitor 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.

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Publications

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77. Behavior of Fish Routed Around a Hydroelectric Dam

USGS scientists are using acoustic cameras to assess the behavior and abundance of bull trout-size fish at the entrance to Oregon's North Fork Reservoir juvenile fish floating surface collector (FSC) to better understand factors that influence fish passage at hydropower dams. The purpose of the FSC is to collect downriver migrating juvenile salmonids and safely route them around the hydroelectric dam. The acoustic cameras also determine if the presence of bull trout-size fish influence the collection or abundance of juvenile salmonids near the FSC. Results from these studies 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.

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Publications

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78. 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 Fishery 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 move through fish passage structures unharmed.

Contact

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Publications

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Hydropower Effects on Fish and Aquatic Resources

79. Evaluating Flow Management as a Strategy to Recover Endangered Pallid Sturgeon in the Upper Missouri River

Habitat fragmentation has been identified as a primary factor in the decline of large river fish species, especially sturgeon that rely on access to free-flowing rivers for spawning and early development. On the upper Missouri River, Fort Peck and Garrison Dams limit the length of free-flowing river available to the endangered pallid sturgeon. These barriers restrict the upstream migration of adults and downstream larval dispersal. USGS scientists evaluated various flow-management scenarios that might aid species recovery. Given the current thermal regime and understanding of pallid sturgeon development, results indicate that the time required for pallid sturgeon embryos to transition to the benthos and initiate feeding might exceed the duration of drift available to them given constraints of reservoir operations. Perturbations to the thermal regime thus influence drift dynamics and may provide options to increase developmental rate, which would, in turn, decrease the length of river required for the dispersal phase of the pallid sturgeon life cycle.

Contact

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Publication

Erwin, S.O., Bulliner, E.A., Fischenich, J.C., Jacobson, R.B., Braaten, P.J., and DeLonay, A.J., 2018, Evaluating flow management as a strategy to recover an endangered sturgeon species in the Upper Missouri River, USA: River Research and Applications, v. 34, no. 10, p. 1254–1266, https://doi.org/10.1002/rra.3371.

80. 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 were conducted from May to August 2018 and again from May to August 2019. 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.

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Publications

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Photograph by U.S. Geological Survey.

Glen Canyon Dam jet tubes releasing water into the Colorado River for a high flow experiment.

81. Effects of Dam Operations on Endangered and Introduced Fish Populations

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, on 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.

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Photograph by U.S. Geological Survey.

Humpback chub specimen in a laboratory tank.

Publications

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Optimizing Dam Operations and Management

82. Adaptive Management of Flows From R.L. Harris Dam on the Tallapoosa River, Alabama

A number of hydroelectric dams across the United States are undergoing a Federal Energy Regulatory Commission process for renewing their licenses. Adaptive management may be a viable path to engage stakeholders as part of this process and ensure stakeholder satisfaction with new management options. The USGS worked with the Alabama Department of Conservation and Natural Resources, Alabama Power Company, USFWS, and R.L. Harris Dam Adaptive Management Stakeholders to determine the best management alternatives for attainment of a suite of objectives outlined in a long-term adaptive management program below R.L. Harris Dam, a large, privately owned dam in Alabama. Stakeholders convened an objective-setting workshop to engage a governance structure and developed a decision support model to determine appropriate actions that optimized stakeholder values. The project led to a Federal Energy Regulatory Commission process for renewing the license to operate the dam.

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Publication

Irwin, E.R., ed., 2019, Adaptive management of flows from R.L. Harris Dam (Tallapoosa River, Alabama)— Stakeholder process and use of biological monitoring data for decision making: U.S. Geological Survey Open-File Report 2019–1026, 93 p., https://doi.org/10.3133/ofr20191026.

83. 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 to 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.

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84. 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.

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Resources

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85. 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 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 such as red swamp and rusty crayfish. 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

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Publications

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Terrestrial and Aquatic Habitats and Ecosystem Functions

Energy development creates a footprint on the terrestrial landscape that can affect wildlife species through changes in the amount and quality of available habitat. Habitat fragmentation may affect species abundance, behavior, and persistence, among other ecological factors. Oil and gas pads, coal and uranium mining operations, and renewable energy facilities occupy a relatively small footprint on the landscape, but the network of roads, power lines, and pipelines needed to connect and support them increases the anthropogenic factors associated with these facilities. USGS scientists are assessing land-use changes associated with energy development and their direct and indirect effects on the quality and quantity of wildlife habitat. Research is also focused on the development of strategies that enhance wildlife habitats while facilitating responsible development.

Photograph by Dan Manier, U.S. Geological Survey.

A country road near Big Piney, Wyoming.

Effects on Terrestrial Habitats

86. Geographic Context in Wind Energy Land Transformation

USGS scientists are studying changes in land-cover associated with new energy facilities and how the impacts change depending on where the facilities are located. Research is focused on overall levels of land transformation and alterations of road networks and how these changes affect the amounts and patterns of undisturbed land cover. This information can assist managers with decisions on how to create opportunities for wind energy production that minimize land-cover change through effective siting.

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Publication

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87. 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 research includes assessment of changes in land-surface temperature, evapotranspiration, and vegetation around wind turbines. This information may be useful to developers and land managers in planning and assessing future wind projects.

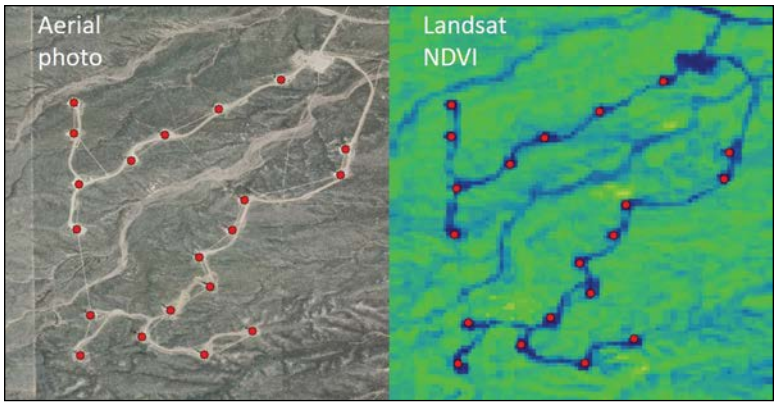

Image by Aaron Johnston, U.S. Geological Survey.

Disturbances from wind farms are visible in imagery from aircraft (left) and satellite (right). Red dots mark turbine locations.

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88. Energy Futures for Wyoming

As part of the 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.

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Publication

Zeigenfuss, L.C., Aikens, E., Aldridge, C.L., Anderson, P.J., Assal, T.J., Bowen, Z.H., Chalfoun, A.D., Chong, G.W., Eddy-Miller, C.A., Germaine, S.S., Graves, T., Homer, C.G., Huber, C.C., Johnston, A., Kauffman, M.J., Manier, D.J., McShane, R.R., Miller, K.A., Monroe, A.P., Ortega, A., Walters, A.W., and Wyckoff, T.B., 2019, U.S. Geological Survey science for the Wyoming Landscape Conservation Initiative—2017 annual report: U.S. Geological Survey Open-File Report 2018–1188, 57 p., https://doi.org/10.3133/ofr20181188.

89. 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 WLCI 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. During 2018, the USGS continued to collect dust samples and quantitatively estimated percent bare ground and plant cover at each collection site. 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.

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90. Potential Effects of Uranium Mining in the Grand Canyon

USGS scientists are working to better understand the potential effects of uranium and other trace elements associated with uranium mining on regional water resources, native plants and animals, and cultural and tribal resources. Wildlife-related studies include characterizing the distribution of uranium and co-occurring elements in terrestrial and aquatic habitats and their potential effects on biota by studying exposure pathways to endemic species and by collecting data to refine bioaccumulation models. Researchers are conducting species surveys, including the use of environmental DNA (eDNA) metagenomic methods, to detect vertebrate and invertebrate species living in and near surface waters near mining activity. Studies are also underway to examine methods of minimizing toxicity to organisms in mine ponds. Finally, researchers are investigating the ability of novel reclamation techniques to stabilize soil at reclaimed mines. Information from these studies can be used by land managers, regulators, industry, and others to understand and mitigate the potential environmental effects of developing breccia-pipe uranium resources.

Contacts

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Photograph by Jo Ellen Hinck, U.S. Geological Survey.

Cliff chipmunk collected outside of the Pinenut Mine, Arizona.

Photograph by Jon Mason, U.S. Geological Survey.

Aerial view of Pinenut Mine and surrounding area, Arizona.

Publications

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91. 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 prey. Despite relatively small site-wide forest loss, waterthrush site quality and nest success declined as shale gas development increased. Avian community composition changed in response to shale gas development. Results from these studies can inform best management practices for gas development.

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Publications

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92. 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 completed studies can assist managers and regulators in evaluating the full impacts of mountaintop mining on the terrestrial environment.

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Publications

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93. 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.

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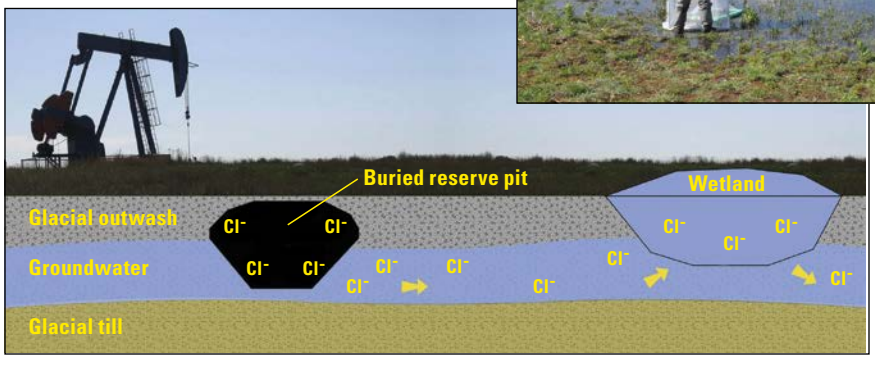
Below: Saline wastewater contamination from legacy energy development sites lead to long-term salinization of wetlands in the Prairie Pothole Region in central North America. Image from Preston and others (2019), Creative Commons 4.0 license.



Above: Scientists work on insect traps in the Prairie Pothole Region of North Dakota. Photograph by Rachel Harrington, U.S. Geological Survey.

Publications

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Effects on Aquatic Habitats

94. Effects of Acid Deposition From Energy Production on Fish and Other Aquatic Species

Watersheds across the United States, including those in the Adirondack Mountains in northern New York, receive high levels of acid deposition of nitrogen and sulfur oxides emitted from power plants and the transportation sector. Acid deposition has been shown to increase acidity and aluminum concentrations in soils and surface waters and affect forest health as well as fish and macroinvertebrate assemblages. USGS scientists are working alongside local, State, and Federal cooperators to characterize the influence of acid-base chemistry on the condition of fish and macroinvertebrate assemblages in lakes and streams in the Adirondacks and other regions, information that is needed for critical loads analyses. The USGS plans to compile and analyze chemical and biological data from multiple datasets and evaluate variations in the health of biological assemblages in streams and lakes that are associated with ongoing impacts and recovery from acid deposition. This research is needed to estimate threshold or target deposition loads of nitrogen and sulfur to watersheds, below which significant harmful effects on sensitive elements of terrestrial and aquatic ecosystems are not expected to occur.

Photograph by Barry Baldigo, U.S. Geological Survey.

Brook trout collected from an Adirondack lake.

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Publications

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

U.S. Geological Survey staff surveying fish assemblages in a Catskill Mountain stream.

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95. Effects of Water Stress From Hydraulic Fracturing on Aquatic Biodiversity and Ecosystem Services in Arkansas

Demand for high-volume, short-duration water withdrawals could create water stress for aquatic organisms in streams sourced for hydraulic fracturing fluids in Arkansas. The USGS and partners estimated potential water stress by using permitted water withdrawal volumes and actual water withdrawals compared to monthly median, low, and high streamflows. Future water stress was predicted to occur in fewer catchments important for drinking water and species of conservation concern due to the decline in new well installations and increased use of recycled water. Accessible and precise withdrawal and streamflow data are critical to assess and mitigate water stress in streams that experience high-volume withdrawals.

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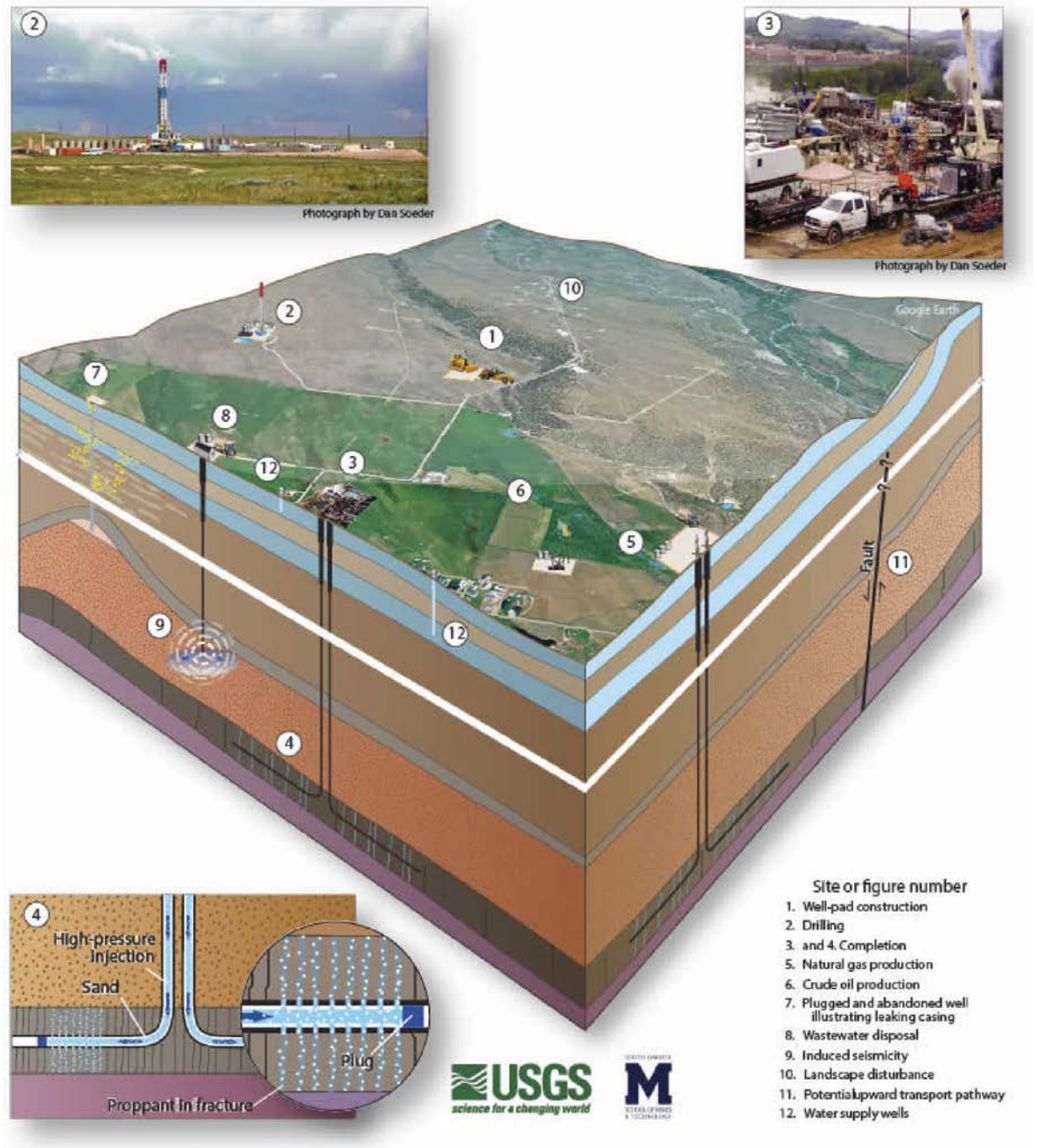
Publication

Entrekin, S., Trainor, A., Saiers, J., Patterson, L., Maloney, K.O., Fargione, J., Kiesecker, J., Baruch-Mordo, S., Konschnik, K., Wiseman, H., Nicot, J.-P., and Ryan, J.N., 2018, Water stress from high-volume hydraulic fracturing potentially threatens aquatic biodiversity and ecosystem services in Arkansas, United States: Environmental Science and Technology, v. 52, no. 4, p. 2349–2358, https://doi.org/10.1021/acs.est.7b03304.

96. Potential Toxicity Associated With Produced Waters From Oil and Gas Activity

The USGS and partners are investigating the potential effects of oil and gas activity on aquatic resources by measuring the levels of inorganic (including salts) and organic compounds in streams following spills or downstream from wastewater facilities. Studies assess toxic thresholds in the laboratory (mimicking field conditions) and potential effects on biological organisms in the field. The USGS is also studying the potential shifts in microbial function, which can alter ecosystem processes, such as nutrient cycling, and can alter the resiliency of a community to perturbation. Results can provide methods for water and sediment monitoring, insight for science support during spills, effective post-spill clean-up practices, and threshold determinations for effects of wastewater discharges on aquatic resources in important rearing areas for migratory waterfowl.



Schematic diagram illustrating unconventional oil and gas (UOG) development activities relevant to research on human-health and environmental impacts (not to scale): well-pad construction (1); drilling (2); completion/stimulation (3, 4); production of natural gas (5) and oil (6) with well casings designed to protect drinking-water aquifers; ultimate closure (plug and abandon), illustrating legacy well with leaking casing (7); wastewater disposal (8); induced seismicity (9); landscape disturbance (10); and potential for transport pathways from deep to shallow formations (11). Also represented are water supply wells in shallow and deep aquifers (12). Image from Soeder and Kent (2018).

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Publications

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97. 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 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.

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Publications

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Conservation and Energy Development Planning and Management Tools

Due to expanding conventional and renewable energy development, decisions regarding siting and permitting of new energy-generation infrastructure are a significant priority for land and resource managers. In support of Federal and State resource management agencies, USGS scientists produce scientific information and project- and landscape-scale tools that can assist resource managers and energy companies in the design and siting of new energy projects to avoid or minimize conflict with fish and wildlife and the critical habitats they depend on. Products include data, models, and tools that can assist managers in prioritizing lands as part of the planning process and for adaptive management at existing energy-generation facilities. Studies focusing on risk assessment help managers evaluate and predict risk to species of conservation concern prior to project design and construction. To better understand effects on vulnerable and rare species, USGS biostatisticians continue to improve statistical tools for more accurate and cost-effective wildlife mortality estimation. Finally, to enhance recovery of degraded terrestrial and aquatic landscapes, USGS scientists are investigating how local and regional practices and conditions influence restoration success, and they are testing novel techniques to improve restoration and recovery of ecosystems.

Photograph by Molly McCormick, U.S. Geological Survey.

Staff from the Bureau of Land Management and the U.S. Geological Survey discuss land management and restoration practices to mitigate risks posed by invasive species.

Planning and Management Support Tools

98. The U.S. Wind Turbine Database

The USGS, in collaboration with the U.S. Department of Energy and the American Wind Energy Association (AWEA), performs quarterly updates of 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 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 assists regulatory agencies, NGOs, and other decision makers in planning and management activities.

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Publication

Hoen, B.D., Diffendorfer, J.E., Rand, J.T., Kramer, L.A., Garrity, C.P., and Hunt, H.E., 2019, United States Wind Turbine Database [USWTDB]: U.S. Geological Survey, American Wind Energy Association, and Lawrence Berkeley National Laboratory data release, USWTDB v. 2.1, July 15, https://eerscmap.usgs.gov/uswtdb.

99. 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, the USGS and partners delineated a migration corridor that identifies areas used by most cranes during their migrations. In partnership with the 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 and management importance to migrating whooping cranes.

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Publications

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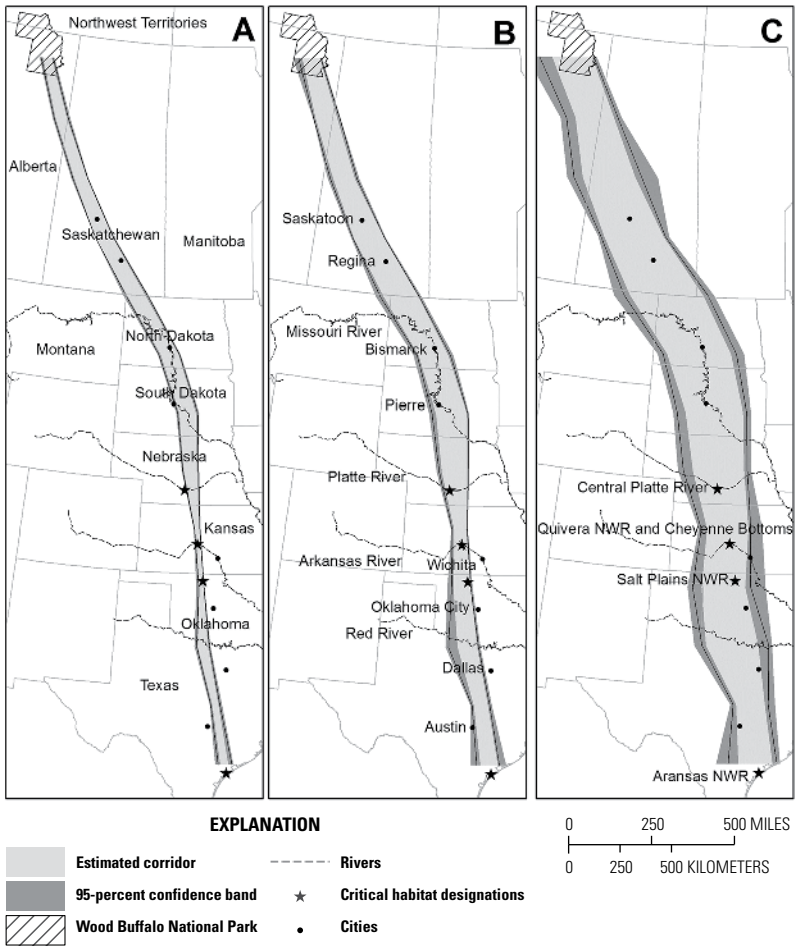

Migration corridors for whooping cranes of the Aransas-Wood Buffalo population, delineating (*A*) 50-percent core, (*B*) 75 percent core, and (*C*) 95-percent core migration areas, with 95-percent confidence bands (from Pearse, Rabbe, Juliusson, and others, 2018).

100. Mapping Probable Suitable Habitat for Rare Plants in California Deserts

State and Federal land managers in California are working to balance renewable energy development with plant and wildlife conservation in California deserts. To support the BLM in planning efforts and conservation of habitat for multiple rare plants, the USGS evaluated existing data and habitat models and developed a process for mapping probable suitable habitat for 26 plant species and potential suitable habitat for 41 plant species. Lands prioritized for renewable energy development contained 3 percent of the habitat modeled as suitable for at least one species. These products can be used by agencies to review proposed projects and plan future plant surveys and by developers to target sites likely to minimize conflicts with rare plant conservation goals.

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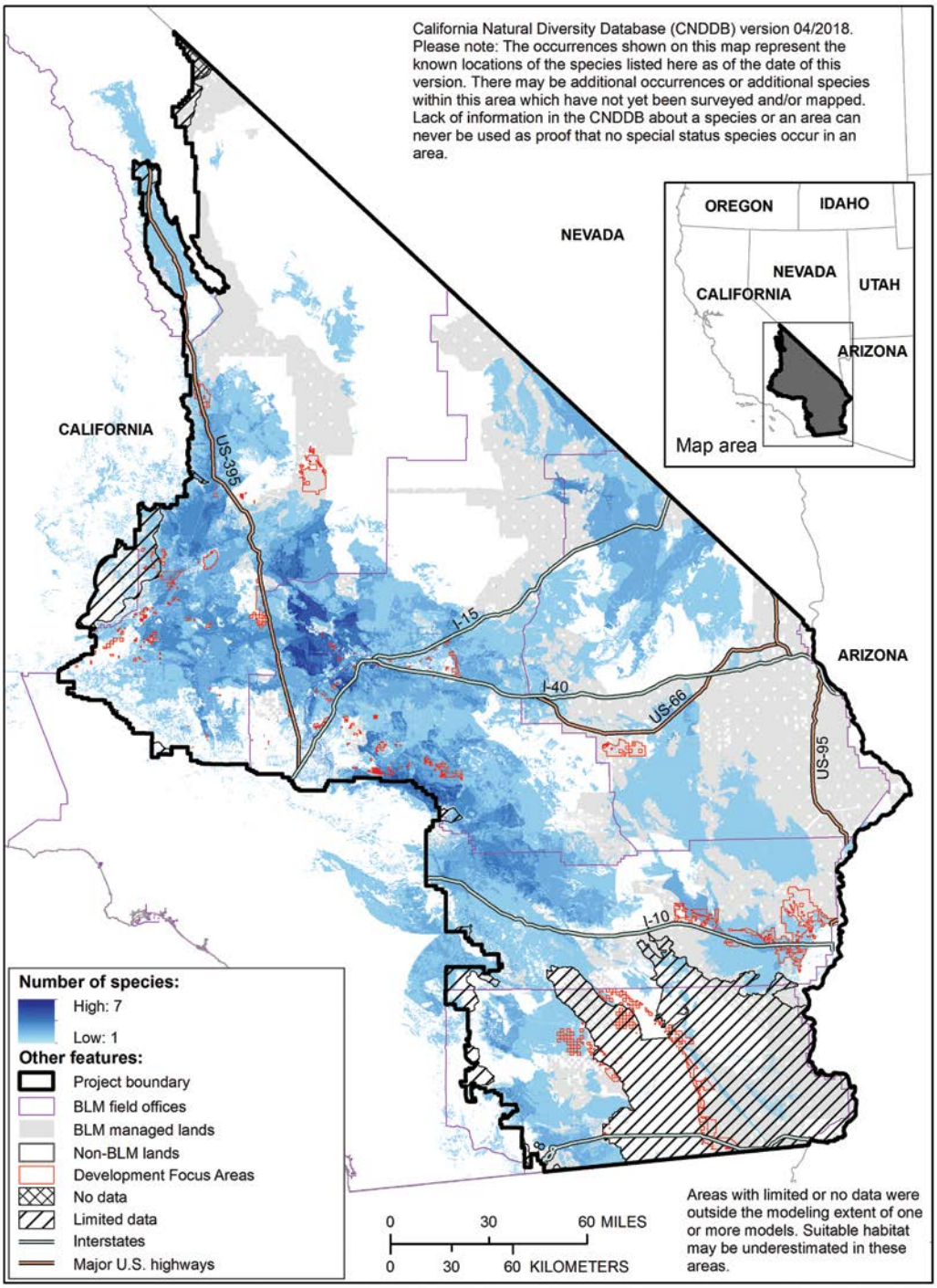
Publication

Reese, G.C., Carter, S.K., Lund, C., and Walterscheid, S., 2019, Evaluating and using existing models to map probable suitable habitat for rare plants to inform management of multiple-use public lands in the California desert: PLOS ONE, v. 14, no. 4, e0214099, 26 p., https://doi.org/10.1371/journal.pone.0214099.



Multispecies map of probable suitable habitat. Shades of blue indicate the number of species for which probable suitable habitat is predicted. Image from Reese and others (2019), Creative Commons CCO.

101. Smart Energy Development in the Sagebrush Ecosystem

The USGS is developing science and decision support tools to inform policy and management decisions about various aspects of the energy development life cycle. These tools are particularly important given ongoing demands for limited natural resources and the need to be cost effective and to make decisions at the broader landscape scale. USGS scientists are working with Federal, State, and industry partners to develop the natural resource knowledge, management tools, risk assessments, and scenario planning that will form the scientific foundation for managers to target areas of high resource potential and low environmental concern and inform effective development.

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Photograph by Ruth Jacobs, U.S. Geological Survey.

Sagebrush grasslands.

102. Effects of Nest Exposure and Spring Temperatures on Eagle Nestling Survival

Golden eagle populations are affected by anthropogenic mortality through shooting, electrocution, poisoning, vehicle strikes, and collision with wind turbines (Millsap and others, 2016), and available tools for mitigating mortality from anthropogenic causes are currently limited to retrofitting power lines, which can reduce electrocutions. To provide the USFWS with additional tools that may mitigate mortality, the USGS tested the effectiveness of artificial shade structures as a method to increase productivity at golden eagle nest sites in the Western United States. USGS, Owyhee Desert Studies, and University of Nevada scientists analyzed 43 years of golden eagle nestling survival data in relation to spring temperatures and nest exposure to the afternoon sun. They predicted that nestling survival in nests exposed to the afternoon sun would be lower than those that were shaded, particularly when there were several hot days during nesting. The study found that golden eagle nestlings reared in nests outfitted with artificial shade structures were more likely to reach fledgling age, supporting the prediction that shaded nests reduce heat-related mortality of nestling golden eagles.

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Publication

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Risk Assessment Tools and Management Strategies

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

Plant community in the Mojave Desert.

103. Factors Influencing Bird Mortality at Utility-Scale Solar Facilities in California

The installed capacity for utility-scale solar power is advancing rapidly in the United States and around the world, but a number of solar facilities in California are linked to varying levels of bird mortality in ways that are poorly understood. The USGS is leading a multipartner project funded by the California Energy Commission and the solar energy industry to examine behavioral, anthropogenic, and landscape factors that may be responsible for bird mortality at solar facilities in the arid Southwest. Ultimately, the research seeks to reduce bird mortality while limiting the impacts on alternative energy generation by (1) identifying potentially viable approaches for deterring birds from approaching solar facilities and (2) informing future siting decisions in ways that reduce the likelihood of birds encountering solar facilities.

Photograph by Robb Diehl, U.S. Geological Survey.

Portable radar near the Desert Sunlight solar energy facility in California.

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Publication

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104. 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.

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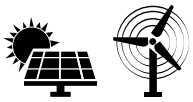
Publication

Sur, M., Belthoff, J.R., Bjerre, E.R., Millsap, B.A., and Katzner, T., 2018, The utility of point count surveys to predict wildlife interactions with wind energy facilities—An example focused on golden eagles: Ecological Indicators, v. 88, p. 126–133, https://doi.org/10.1016/j.ecolind.2018.01.024.



105. 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.

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Publications

Katzner, T.E., Nelson, D.M., Braham, M.A., Doyle, J.M., Fernandez, N.B., Duerr, A.E., Bloom, P.H., Fitzpatrick, M.C., Miller, T.A., Culver, R.C.E., Braswell, L., and DeWoody, J.A., 2017, Golden eagle fatalities and the continental-scale consequences of local wind-energy generation: Conservation Biology, v. 31, no. 2, p. 406–415, https://doi.org/10.1111/cobi.12836.

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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 approaches to compare impacts across energy types 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 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 greater sage-grouse core area policy on shaping landscape patterns and wildlife habitat quality.

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Publications

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107. 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 and implementing approaches for assessing population-level impacts of wind energy on birds and bats. This research can assist conservation managers with wind energy project permitting and the use and interpretation of monitoring protocols for wind facilities.

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Publications

Beston, J.A., Diffendorfer, J.E., Loss, S.R., and Johnson, D.H., 2016, Prioritizing avian species for their risk of population-level consequences from wind energy development: PLOS ONE, v. 11, no. 3, e0150813, 19 p., https://doi.org/10.1371/journal.pone.0150813.

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108. 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.

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Publications

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Novel Techniques in Species Detection and Monitoring for Energy Planning and Conservation

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

Many remote sensing methods designed to guide wind turbine curtailment in the presence of birds and bats (for example, cameras and portable radar) represent widespread deployment of new sensor networks that may add considerable complexity and cost to wind energy operators in the United States. The most feasible solutions to minimizing wind energy impacts on birds and bats typically are easy to deploy, inexpensive to operate, and highly reliable, and they require little maintenance and minimize energy generation losses. 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 accurately monitor bird and bat movements at wind facilities across much of the continental United States. If this approach is validated, the NEXRAD system could then serve as a low-cost, low-maintenance platform to inform smart curtailment of wind energy operations in the presence of birds and bats.

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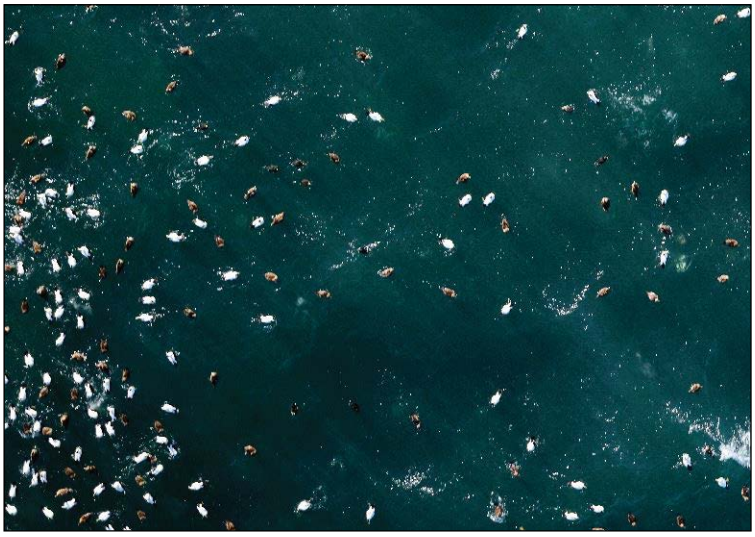
110. Automated Detection and Classification of Waterfowl, Seabirds, and Other Wildlife on the Outer Continental Shelf

In collaboration with BOEM, USFWS, and the International Computer Science Institute Vision Group, USGS scientists are developing deep learning algorithms and tools for the automatic detection and classification of waterfowl, seabirds, and other marine wildlife from digital aerial imagery. In addition, USGS scientists are conducting quarterly aerial surveys that can provide baseline information on wildlife distributions, abundance, and movements by season. This information can inform environmental assessments and impact analyses of potential wildlife exposure to offshore energy development projects on the U.S. Atlantic OCS. Automated methods can also be used to improve the safety, efficiency, and accuracy of migratory bird surveys regularly conducted by the USFWS in the Great Lakes.



Photograph by Bureau of Ocean Energy Management.

Aerial photograph of a mixed flock of sea ducks, including common eiders and black scoters.

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111. Advancing Wildlife Monitoring 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. Such advances include new methods of quantification and the use of machine learning to improve discrimination of different types 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.

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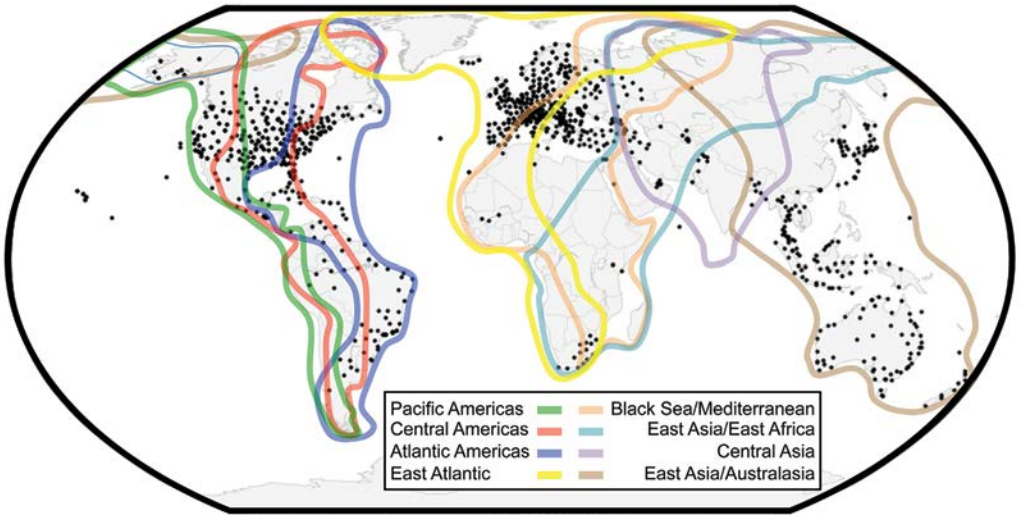

Global overview of weather radar sites registered with the World Meteorological Organization, with the major global flyways superimposed. Flyways were obtained from http://www.birdlife.org/worldwide/programme-additional-info/migratory-birds-and-flyways. Image from Hüppop and others (2019), Creative Commons 3.0 license.

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112. Monitoring Golden Eagle Nests, Prey, and Behavior Using Cameras

Boise State University and USGS scientists described a less invasive way to monitor golden eagle nests built on steep canyon walls by using motion-activated trail cameras. They found that camera observations recorded twice the number of prey as laboratory examination of prey remains and pellets, were more likely to detect the smallest and largest prey, and cost half as much as laboratory examination. Cameras recorded productivity, fledging dates, and in one case, a nestling death. Trail cameras may be a reliable and cost-effective option to obtain information about eagle behavior and nest contents. In addition, 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. Detailed information about golden eagle prey can help prioritize prey management and develop conservation strategies.

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Publications

Bedrosian, G., Watson, J.W., Steenhof, K., Kochert, M.N., Preston, C.R., Woodbridge, B., Williams, G.E., Keller, K.R., and Crandall, R.H., 2017, Spatial and temporal patterns in golden eagle diets in the Western United States, with implications for conservation planning: Journal of Raptor Research, v. 51, no. 3, p. 347–367, https://doi.org/10.3356/JRR-16-38.1.

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113. eDNA Applications in Freshwater and Ocean Environments

USGS scientists are developing standards and methodologies for applying molecular and genetic studies, including eDNA, in freshwater and ocean environments. Recent advances include a methodology that improves eDNA yield and quality from water samples. In addition, USGS geneticists used eDNA to estimate occurrence in vulnerable manatee populations and showed that eDNA-derived detection estimates for manatees were higher than those generated by using aerial survey data on the west coast of Florida, indicating that the use of eDNA is effective for population monitoring. Cutting-edge

genomic resources and techniques can provide resource managers with new ways of monitoring rare and cryptic species, as well as the ability to more easily characterize the biodiversity of remote or poorly studied ecosystems. This information can be used by resource managers to inform energy development decisions in freshwater and ocean environments.

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Publications

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114. 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.

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Publications

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Fatality Estimation Tools

115. 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 have developed software that combines multiple approaches under a single generalized estimator (GenEst). GenEst allows the user to evaluate assumptions regarding input parameters and select the approach that best reflects the situation and data. The applicability of GenEst is not limited to wind power facilities. The tool is 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.

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Photograph by U.S. Geological Survey.

U.S. Geological Survey and U.S. Fish and Wildlife Service staff at a solar energy facility in southern California. A solar trough reflects the sun's rays towards a solar collector.

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116. Developing a Model to Estimate Eagle-Carcass Density 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. Models of how carcass density changes with distance from wind turbines are needed to account for eagle carcasses missed in unsearchable areas. Because bald and golden eagles are not found in adequate numbers at any single wind facility in the United States to allow for reliable estimation of eagle-carcass density, USGS researchers are using data from white-tailed eagles at the Smøla wind facility in Norway as surrogates. Eagle data from several sites in California will then be compared to the white-tailed eagle model to assure its applicability to large raptors in the United States. Results can be used by the USFWS in estimating post-construction eagle mortality.

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117. 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.

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Publications

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Terrestrial Habitat Restoration Following Energy Development

Photograph by Mike Duniway, U.S. Geological Survey.

Oil pad near Vernal, Utah.

118. Evaluating Reclamation Success Following Oil and Gas Development

Photograph by Jessica Mikenas, U.S. Geological Survey.

USGS soil scientist records vegetation data on a decommissioned well pad in Utah.

USGS scientists are implementing a range of scientific approaches to improve reclamation success following oil and gas development in Utah, Colorado, and New Mexico. In collaboration with the BLM, USFWS, and industry partners, reclamation experiments are testing seed mixes, soil and site modifications, soil stabilizers, and other novel approaches. USGS scientists are also assessing vegetation conditions and dust generation following oil and gas drilling activities across the region. Studies are incorporating satellite imagery, digital soil mapping, predictive ecological modeling, and field assessments to evaluate vegetation recovery and dust production following well pad abandonment. Results of monitoring and modeling horizontal aeolian sediment movement, including dust, suggest that unpaved roads and plugged and abandoned well pads have more windblown sediment transport than surrounding rangelands, and results show variation between local soil types and vegetation communities where wells and roads are located. This suite of research activities can help resource managers make informed decisions for future well pad and infrastructure development.

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Publications

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119. 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 a clear understanding of spatial and temporal factors influencing recovery across the landscape. USGS and Colorado State University 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 recovery times of sagebrush across broad scales and assess the effects of factors such as weather and soils on outcomes. This information and resulting spatial data can help inform future development and planning processes.

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120. 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 sagebrush productivity and detect monthly anomalies associated with drought-related sagebrush mortality to document the extent and severity of the disturbance. Scientists are also producing maps that highlight areas for plant community assessment. During 2018, scientists visited 10 sites affected by drought and 10 sites unaffected by drought to develop sampling protocols designed to discern patterns of vegetation anomalies at multiple scales. These protocols will be applied during the 2019 and 2020 growing seasons. 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.

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Publication

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121. Method for Assessing the Ecological Integrity of Federal Lands in Nevada

Public lands in the Western United States are managed for diverse uses such as timber harvest, livestock grazing, energy development, and wildlife conservation. The USGS and partners proposed a method for assessing ecological integrity on multiple-use lands and applied the method to evaluate shrublands in Nevada. The approach yielded an assessment based on six indicators of ecosystem structure, function, and composition, including resource- and stressor-based indicators measured at multiple scales. Results may inform efforts to control invasive species and restore shrublands on Federal lands in Nevada.

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Publication

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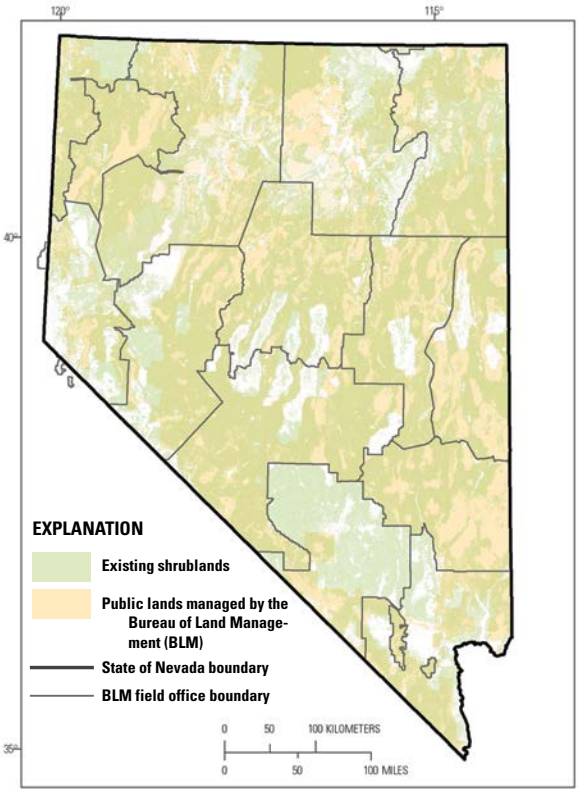

Current and historic shrublands and public lands managed by the BLM in Nevada.

Image from Carter and others (2019), Creative Commons 4.0 license.

122. 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.

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123. Restoration Assessment and Monitoring Program for the Southwest

The Restoration Assessment and Monitoring Program for the Southwest (RAMPS) seeks to assist Federal and State land management agencies in developing successful techniques for improving land conditions in dryland ecosystems of the Southwestern United States. Invasion by nonnative species, wildfire, drought, energy development, and other disturbances are increasing in extent and frequency, creating novel ecosystem conditions that can outpace the knowledge base of local land managers. These growing problems often cross administrative boundaries, requiring agencies to proactively work together. Considering these challenges, managers can benefit from collaborative, innovative, and dynamic approaches to sharing information. To meet this need, RAMPS has created a hub for science-based information and tools to help managers identify effective and resource-efficient strategies to successfully restore degraded areas.

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Publications

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124. Distributed Field Trial Network for Dryland Restoration

Recovery from disturbance represents a substantial challenge to agencies that manage large tracts of land in the Southwest. Researchers at the USGS, Northern Arizona University, University of Arizona, New Mexico State University, and University California, Riverside, are working with land managers from the BLM, NPS, USFWS, Navajo Nation National Heritage Program, Diablo Trust Ranches, Babbit Ranches, and The Nature Conservancy to develop RestoreNet, a network of restoration field trial sites covering the Colorado Plateau and Sonoran, Chihuahuan, and Mojave Deserts. The goals of RestoreNet are to provide information to land managers on methods to improve restoration outcomes, assess the ecosystem services (for example, forage, erosion control, soil fertility, pollination) provided by restored species and communities, complement existing knowledge on development of native plant materials, and minimize costs of developing new infrastructure. The RestoreNet network of field sites can help test novel restoration treatments and serve as demonstration sites for land managers and practitioners.

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Additional Resource

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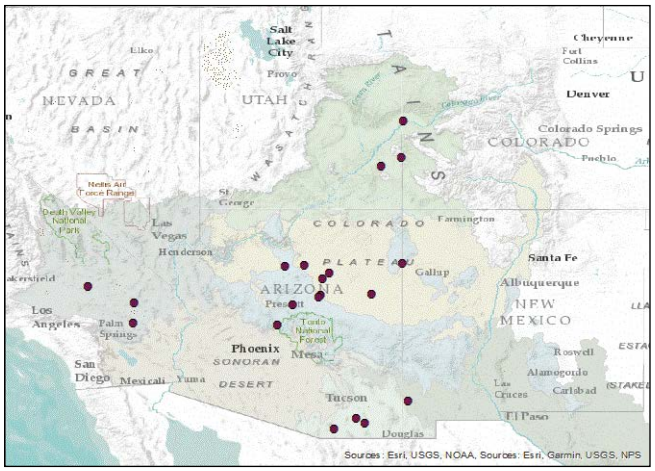

Image from U.S. Geological Survey.

RestoreNet has sites located across ecosystems of the Southwestern United States.

Aquatic Habitat Restoration and Recovery Following Dam Removal

125. Reintroduction of Anadromous Salmonids to Reservoirs Above Hydroelectric Dams

The reintroduction of extirpated salmonids to historically occupied areas is becoming increasingly common as a conservation and recovery strategy. USGS scientists are evaluating the feasibility of reintroducing native salmonids to reservoirs and tributaries upstream of hydropower dams in northern California, Oregon, and Washington. Reservoirs serve both as functional migration corridors and profitable juvenile-rearing habitats despite hosting abundant predator populations. Scientists evaluated consumption demand and seasonal food availability as well as potential predation mortality to juvenile anadromous salmonids. In a new study for the Yale Lake and Lake Merwin hydropower projects in Washington State, scientists used a combination of field data and existing information to address key objectives related to the reintroduction of salmonids and to inform decisions about fish passage. These approaches 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.

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Publications

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126. Ecological Effects of 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 economically 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.

Photograph by Jeff Duda, U.S. Geological Survey.

The Elwha River, Washington, following dam removal.

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Publications

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127. A Multiscale Approach to Balance Tradeoffs Among Dam Infrastructure, River Restoration, and Cost

Aging infrastructure and growing interests in river restoration have led to a substantial rise in dam removals in the United States; however, the decision to remove a dam involves many complex tradeoffs. The USGS and partners assessed the tradeoffs and synergies involved with coordinated dam removal at three spatial scales in New England. They found that increasing the spatial scale affected by dam decisions improves tradeoffs among ecosystem services, river safety, and cost, but the benefits of large-scale river restoration vary dramatically by location. The model may help facilitate future dam-decision negotiations by identifying appropriate scales, locations, and criteria that satisfy multilateral funding, policy, and stakeholder goals.

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Publications

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List of Species

Common name	Scientific name
Agassiz's desert tortoise	*Gopherus agassizii*
Alewife	*Alosa pseudoharengus*
American eel	*Anguilla rostrata*
American shad	*Alosa sapidissima*
Ashy storm-petrel	*Oceanodroma homochroa*
Atlantic salmon	*Salmo salar*
Atlantic sturgeon	*Acipenser oxyrinchus*
Bald eagle	*Haliaeetus leucocephalus*
Barren-ground caribou	*Rangifer tarandus groenlandicus*
Bighead carp	*Hypophthalmichthys nobilis*
Black scoter	*Melanitta nigra*
Black storm-petrel	*Oceanodroma melania*
Black-legged Kittiwake	*Rissa tridactyla*
Black-tailed jackrabbit	*Lepus californicus*
Blueback herring	*Alosa aestivalis*
Brewer's sparrow	*Spizella breweri*
Brook trout	*Salvelinus fontinalis*
Brown booby	*Sula leucogaster*
Brown pelican	*Pelecanus occidentalis*
Brown trout	*Salmo trutta*
Bubblegum coral	*Paragorgia arborea*
Bull trout	*Salvelinus confluentus*
California brown pelican	*Pelecanus occidentalis californicus*
California condor	*Gymnogyps californianus*
Capelin	*Mallotus villosus*
Caribou	*Rangifer tarandus*
Chinook salmon	*Oncorhynchus tshawytscha*
Cliff chipmunk	*Tamias dorsalis*
Coho salmon	*Oncorhynchus kisutch*
Common eider	*Somateria mollissima*
Common loon	*Gavia immer*
Common merganser	*Mergus merganser*
Common murre	*Uria aalge*
Common raven	*Corvus corax*
Desert globemallow	*Sphaeralcea ambigua*
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*
Green sea turtle	*Chelonia mydas*

Common name	Scientific name
Gulf sturgeon	*Acipenser oxyrinchus*
Harlequin duck	*Histrionicus*
Hawaiian hoary bat	*Lasiurus cinereus semotus*
Hoary bat	*Lasiurus cinereus*
Honey bee	*Apis mellifera*
Horned grebe	*Podiceps auritus*
Horned lark	*Eremophila alpestris*
Humpback chub	*Gila cypha*
Indiana bat	*Myotis sodalis*
Keen's myotis	*Myotis keenii*
Kemp's ridley	*Lepidochelys kempii*
Lake sturgeon	*Acipenser fulvescens*
Laysan albatross	*Phoebastria immutabilis*
Least tern	*Sternula antillarum*
Lesser prairie-chicken	*Tympanuchus pallidicinctus*
Lesser scaup	*Aythya affinis*
Little brown bat	*Myotis lucifugus*
Loggerhead	*Caretta*
Long-tailed duck	*Clangula hyemalis*
Louisiana waterthrush	*Parkesia motacilla*
McCown's longspur	*Rhynchophanes mccownii*
Meadow fritillary	*Boloria bellona*
Mexican free-tailed bat	*Tadarida brasiliensis*
Milkweed	*Asclepias spp.*
Mohave ground squirrel	*Xerospermophilus mohavensis*
Monarch butterfly	*Danaus plexippus*
Mule deer	*Odocoileus hemionus*
Northern gannet	*Morus bassanus*
Northern long-eared bat	*Myotis septentrionalis*
Northern right whale dolphin	*Lissodelphis borealis*
Pacific blue mussel (foolish mussel)	*Mytilus trossulus*
Pacific lamprey	*Entosphenus tridentatus*
Pacific loon	*Gavia pacifica*
Pacific sand lance	*Ammodytes hexapterus*
Pacific walrus	*Odobenus rosmarus divergens*
Pallid sturgeon	*Scaphirhynchus albus*
Piping plover	*Charadrius melodus*
Polar bear	*Ursus maritimus*
Pronghorn	*Antilocapra americana*
Quagga mussel	*Dreissena bugensis*
Rainbow trout	*Oncorhynchus mykiss*
Red-breasted merganser	*Mergus serrator*
Red-footed booby	*Sula*
Red-necked grebe	*Podiceps grisegena*
Red swamp crayfish	*Procambarus clarkii*
Red-tailed tropicbird	*Phaethon rubricauda*
Red-throated loon or red-throated diver	*Gavia stellata*

List of Species—Continued

Common name	Scientific name
Roseate tern	*Sterna dougallii*
Round goby	*Neogobius melanostomus*
Rusty crayfish	*Orconectes rusticus*
Rusty patched bumble bee	*Bombus affinis*
Sage thrasher	*Oreoscoptes montanus*
Sagebrush sparrow	*Artemisiospiza nevadensis*
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*
Sockeye salmon	*Oncorhynchus nerka*
Spectacled eider	*Somateria fischeri*
Steelhead	*Oncorhynchus mykiss*
Surf scoter	*Melanitta perspicillata*
Swainson's hawk	*Buteo swainsoni*
Swamp milkweed	*Asclepias incarnata*
Townsend's big-eared bat	*Corynorhinus townsendii*
Wedge-tailed shearwater	*Puffinus pacificus*
Western toad	*Anaxyrus boreas*
White-tailed eagle	*Haliaeetus albicilla*
White-tailed jackrabbit	*Lepus townsendii*
White-winged scoter	*Melanitta deglandi*
Whooping crane	*Grus americana*
Woolly paperflower	*Psilostrophe tagetina*
Yellow-billed loon	*Gavia adamsii*
Zebra mussel	*Dreissena polymorpha*

Pair of spectacled eiders flying near the Colville River, Alaska. Photograph by Ryan Askren, U.S. Geological Survey.

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