Report to the Fish and Wildlife Health Committee
of the Association of Fish and Wildlife Agencies
from USGS Science Centers
September 11, 2013

Creating a National Fish and Wildlife Health Network

An integrated, national network for coordinating fish and wildlife disease surveillance, laboratory analysis, information dissemination, communication, and response across federal, state and tribal agencies and other stakeholders is imperative. To achieve this, a multi-disciplinary group of wildlife professionals from federal, state, and non-governmental organizations is proposing to create a National Fish and Wildlife Health Network. This Network will establish a collaborative framework by which government agencies, tribes, universities, and professional conservation organizations can cooperate and assist tribal, state, and federal agencies to manage diseases of free-ranging fish and wildlife. The mission of the Network will be achieved through partnerships and the collective adoption of protocols, procedures, and actions to address fish and wildlife health issues. A Coordinating Committee will be established to create, oversee, and coordinate implementation of the Network; the committee will be a partnership of public and private sectors assembled to promote and guide actions of the Network. The primary stakeholders and users of this Network are those tribal, state, and federal government agencies responsible for managing the health of free-ranging fish, terrestrial wildlife, and marine animal populations and their diseases. The Network will initially focus on: 1) wildlife diagnostic laboratory protocols; 2) disease information management and dissemination; 3) coordinated disease surveillance; 4) interagency communication and response plans; and 5) species specific health issues. The Network will address deficiencies in fish and wildlife disease monitoring and prevention programs where they exist, and facilitate the work of existing systems. Creating this Network will be an important step in addressing the critical need to protect the Nation's fish and wildlife health. **Contact:** Jonathan Sleeman, 608-270-2401, jsleeman@usgs.gov.

Wildlife Highlights

Sylvatic plague vaccine for prairie dogs

Laboratory studies have demonstrated that oral vaccination of prairie dogs against plague using raccoon pox-vectored vaccine is feasible, resulting in significant protection against challenge with *Yersinia pestis*, the bacterium that causes sylvatic plague. The Sylvatic Plague Vaccine (SPV) Subcommittee, under the direction of the Executive Committee of the Black-footed Ferret Recovery Implementation Team, is continuing its work to complete development and delivery of the sylvatic plague vaccine as a management tool to combat plague in prairie dogs and promote the recovery of the black-footed ferret. Field trials completed in 2012 confirmed the safety of the vaccine in wild prairie dogs and non-target animals. Field studies to assess vaccine efficacy in free-ranging prairie dogs are currently underway. Vaccine and placebo baits have already been distributed in select prairie dog colonies in Montana, Wyoming, Utah, Colorado, and South Dakota. **Contact**: Tonie Rocke, National Wildlife Health Center, 608-270-2451, trocke@usgs.gov.

Examining the effects of density on bighorn sheep lamb recruitment

Bighorn sheep lamb recruitment is a significant problem affecting many bighorn sheep herds throughout the West, and limiting overall health of this species across its range. One hypothesis about the drivers of lamb recruitment is that it may be a manifestation of density-dependent effects, which are well-documented in other ungulate species. The National Wildlife Health Center and Colorado Parks and Wildlife are working collaboratively to investigate this hypothesis by conducting field experiments to determine if changing density can improve lamb recruitment. **Contact:** Daniel Walsh, 608-270-2481, dwalsh@usgs.gov

Identifying areas to focus CWD surveillance in Montana

Chronic wasting disease is a prion disease fatal to mule deer, white-tailed deer, elk, and moose. CWD has been detected in all states and provinces bordering Montana with the exception of Idaho, and is present in

wild ungulate populations within 100 miles of the Montana border in Wyoming and the Black Hills of South Dakota and within 50 miles of the border in Canada. CWD has the potential to have significant economic and ecological impacts in Montana, which has traditionally been an ungulate hunting destination for hunters worldwide. The National Wildlife Health Center and Montana Fish, Wildlife, and Parks are working together to model deer movements in Montana and identify areas with high densities of deer in proximity to known infected populations. These models will assist MFWP in targeting surveillance to at-risk herds. **Contact:** Robin Russell, 608-270-2474, rerussell@usgs.gov

Polar bears: Development of a gene transcript panel

In 2012, the USGS Alaska Science Center Polar Bear Research Program began a study with the USGS Western Ecological Research Center to develop a gene transcript panel that can be used to identify potential environmental perturbations or stressors within individuals and populations. In 2013, the project was expanded from the southern Beaufort Sea subpopulation to also include individuals sampled in the Chukchi Sea subpopulation of Alaska. The expanded project will allow for a comparison of physiologic responses to stressors between subpopulations exposed to differing thresholds of industrial development. **Contact:** Tony DeGange, 907-786-7000, tdegange@usgs.gov

USGS wildlife disease and environmental health in Alaska—New Fact Sheet provides information on USGS research

Environmental health is defined by connections between the physical environment, ecological health, and human health. Current research by the U.S. Geological Survey recognizes the importance of this integrated research philosophy, which includes study of disease and pollutants as they pertain to wildlife and humans. Alaska is an international crossroads for millions of migratory wildlife species. These intercontinental migratory links and changes in current and future climate may play important roles in the transmission of diseases that affect wildlife and humans. The U.S. Geological Survey has published a new Fact Sheet to highlight on-going field and laboratory research in the area of wildlife disease and environmental health. Citation: The Fact Sheet is online at: http://pubs.usgs.gov/fs/2013/3027/

Cornwell, E.R., G.E. Eckerlin, T.M. Thompson, W.N. Batts, R.G. Getchell, G.H. Groocock, G. Kurath, J.R. Winton, R.N. Casey, J.W. Casey, M.B. Bain and P.R. Bowser. 2012. Predictive factors and viral genetic diversity for viral hemorrhagic septicemia virus type IVb infection in Lake Ontario and the St. Lawrence River. Journal of Great Lakes Research 38:278-288.

Emmenegger, E., C. H. Moon, P. Hershberger and G. Kurath. in press. Virulence comparison of viral hemorrhagic septicemia virus (VHSV) genotypes Ia, Iva, IVb, and IVc in salmonid, cyprinid, clupeid, and percid fishes. Diseases of Aquatic Organisms

Faisal, M., M. Shavalier, R.K. Kim, E.V. Millard, M.R. Gunn, A.D. Winters, C.A. Schultz, A. Eissa, M.V. Thomas, M. Wolgamood, G.E. Whelan and J. Winton. 2012. Spread of the emerging viral hemorrhagic septicemia virus strain, genotype IVb, in Michigan, USA. Viruses 4:734-760.

Gregg, J.L., C.A. Grady, C.S. Friedman and P.K. Hershberger. 2012. Inability to demonstrate fish-to-fish transmission of *Ichthyophonus* from laboratory-infected Pacific herring *Clupea pallasii* to naïve conspecifics. Diseases of Aquatic Organisms 99: 139-144.

Kocan, R., S. LaPatra and P. Hershberger. 2013. Evidence for an amoeba-like stage of *Ichthyophonus* sp. and description of a circulating blood stage: A probable mechanism for dispersal within the fish host. Journal of Parasitology 99:235-240.

Kurath, G., J.C. Jolley, T.M. Thompson, D. Thompson, T.A. White, and J.R. Winton. in press. Pacific lamprey Enterosphenus tridentatus ammocoetes are not susceptible to common fish rhabdoviruses of the Pacific Northwest. Journal of Aquatic Animal Health

Wargo, A.R., A.M. Kell, R.J. Scott, G.H. Thorgaard and G. Kurath. 2012. Analysis of host genetic diversity and viral entry as sources of between-host variation in viral load. Virus Research 165:71-80.

USGS manatee research in Guantanamo Bay, Cuba
USGS-SESC scientists Dr. Bob Bonde, Dr. Dan Slone, Jim Reid, and Susan Butler recently completed the first wild manatee captures at Naval Station Guantanamo Bay, Cuba. Health assessments conducted on 4 manatees included collecting clinical samples and data on body condition. Their field work also included satellite tagging 3 of these individuals to remotely monitor their movements and use of local freshwater and seagrass habitats. **Contact:** Jim Reid, 352-264-3546, jreid@usgs.gov

Manatee health assessments in Belize
Dr. Robert Bonde and Cathy Beck, SESC, conducted manatee health assessments at 2 sites in Belize from May 27 - June 9, 2013, as part of a long-term, collaborative research effort on Antillean manatees which began in 1997. Working with Sea to Shore Alliance, the Belize Forestry and Fisheries Departments, and the Belize Coastal Zone Management Authority and Institute, 11 manatees were captured and assessed, and 4 were radiotagged with satellite and VHF transmitters. Belizean and other biologists and students were trained in field sampling and capture techniques. Biological samples were imported under CITES authority for the USGS, SESC archive for planned and future collaborative research.
Contact: Cathy Beck, 352-264-3550, cbeck@usgs.gov

Decision support for assessing waterbird and landbird movements and habitat use in interior landscapes and the Upper Great Lakes in relation to potential wind energy development
The USGS is using various configurations of marine radar, as well as NEXRAD, and aerial and ground survey methods to document airspace and landscape use of migratory birds. Species and groups under study at present include sandhill cranes refuging during fall migration in Wisconsin, pelagic and nearshore waterbirds wintering in the western Great Lakes, and songbirds in transit during spring and fall migration along the southern shore of Lake Erie and along the Upper Mississippi River. Basic natural history information is being gathered and data are being used to investigate relations with anthropogenic structures and environmental stressors. The scientists are updating computing hardware to fully employ the software program radR to conduct real-time and post-processing of radar tracks collected with marine radar. University partners are helping with design of cost effective hardware connections to radar systems
Contact*:* Eileen Kirsch, USGS Upper Midwest Environmental Sciences Center, ekirsch@usgs.gov, 608-781-6226

Wind energy development on migratory bats
The USGS Energy Program is working to develop a quantitative framework for understanding the effects of wind energy development on migratory bats. Scientists from the Upper Midwest Environmental Sciences Center are developing migratory connectivity models for the Indiana (*Myotis sodalis*) and little brown bats (*M. lucifugus*). The Indiana bat is listed as Endangered under the Endangered Species Act, whereas the little brown bat is currently under consideration for listing. Currently, a theoretical framework has been developed that provides insight into the effects of wind energy on migratory patterns and spatial dynamics of bats. Future work will focus on parameterizing and applying this model to bat populations using data from the USFWS. In addition to wind-energy, the model will consider the synergistic effects of White-nose Syndrome and be expandable to assess the effects of climate change and other stressors on migratory bat species. The model being developed for bats will also be generalizable to other species and the project's long term plans include researching what model features and attributes are necessary to assess the impact of wind energy on a suite of wildlife species. **Contact:** Wayne Thogmartin, Upper Midwest Environmental Sciences Center, wthogmartin@usgs.gov

New query tool makes available data on Florida's protected terrestrial vertebrates
A new online query tool known as the "Threatened and Endangered Vertebrates in Florida," will make basic biological data more readily accessible for Florida's 26 threatened and endangered terrestrial vertebrates—including the Florida panther, American crocodile, and Key deer, among other species. The tool was developed by a team of researchers from the University of Florida, the U.S. Fish and Wildlife Service, the U.S. Geological Survey, and the U.S. National Park Service and is being made available to the public by Joint Ecosystem Modeling (JEM), a partnership among federal and state agencies, universities, and other organizations. Contact: Stephanie Romanach, 754-264-6060,sromanach@usgs.gov

SESC manatee health assessments in Crystal River, FL
SESC scientists Drs. Bob Bonde and Maggie Hunter, Cathy Beck, Jim Reid, Susan Butler, Amy Teague, Gaia Meigs-Friend, Michele Davis, Kaylee Brown, and Buddy Hyde were joined by Gary Hill and Mark Blouin of the St Petersburg CMSC of the USGS, along with USFWS Crystal River National Wildlife Refuge Manager Michael Lusk and staff, George Kenney with DOD, biologists from the FWC, and veterinarians, researchers, and students from the University of Florida, conducted manatee health assessment captures in Crystal River on October 20, 2012. Two healthy manatees, including a large middle-stage pregnant cow, were captured using nets and monitored during the detailed biomedical assessments. Samples and biological data were collected. The team was racing the wind-driven tidal surge due to very strong winds from the west, so dry beach was limited. Additional manatee captures are planned for Crystal River in November and February. **Contact**: Bob Bonde, 352-264-355, rbonde@usgs.gov

Disease Investigations

White-nose syndrome winter 2012/2013 summary
White-nose syndrome (WNS) was confirmed in cave-hibernating bats in three new states (South Carolina, Georgia, and Illinois) and one new province (Prince Edward Island) during the 2012/2013 winter season. In addition, Arkansas and Minnesota recently reported the genetic detection of *Geomyces destructans*, the causative agent of WNS, from research surveillance samples collected from hibernacula during the previous winter. This represents a continued expansion of *G. destructans* distribution on the landscape; thus far, no evidence exists of geographic barriers preventing its spread. White-nose syndrome is now confirmed in 22 states and 5 Canadian provinces since it was first recognized near Albany, New York in 2007. Numerous additional counties throughout Tennessee, Kentucky, and Ohio had confirmed cases of WNS this winter indicating that within two years of its initial detection in these areas, the disease is now endemic in these states. Sites in several northeastern states —where WNS has been present the longest— continue to be occupied by bats although in much lower numbers than before the disease struck. Several states within the endemic area report an increase in bat populations at some sites during winter bat counts. It is unclear if this population increase represents immigrants from other sites and/or a shift in roosting location of the local bat population from un-surveyed portions of the hibernaculum. Winter hibernacula survey data are being reviewed by state and federal management agencies to better understand the on-going impacts of WNS on bat populations in affected regions. Also of note, *G. destructans* DNA has been detected on endangered Virginia big-eared bats (*Corynorhinus townsendii virginianus*) hibernating in at least one known contaminated site; no mortality or visible signs of disease are reported in this species at this time. Recent phylogenetic analyses by U.S. Forest Service scientists have demonstrated the WNS fungus is more closely related to the genus *Pseudogymnoascus* rather than *Geomyces*. Thus the fungus has been reclassified as *P. destructans*. This reclassification allows scientists to more easily determine how this fungus is related to other fungi and determine what its closest relatives are. In doing this, it may also help scientists to determine why this particular fungus is pathogenic whereas its close relatives are not. For the latest WNS updates, consult NWHC Wildlife Health Bulletins at: http://www.nwhc.usgs.gov/publications/wildlife_health_bulletins/index.jsp. Current NWHC bat submission guidelines are available at: http://www.nwhc.usgs.gov/disease_information/white-nose_syndrome/USGS_NWHC_Bat_WNS_submission_protocol.pdf. **Contact**: Anne Ballmann, National Wildlife Health Center, 608-270-2445, aballmann@usgs.gov

Investigation of snake fungal disease east of the Mississippi River (United States)
Since 2006, there has been an increase in the number of reports of skin infections in wild snakes in certain parts of the eastern United States. Laboratory testing has implicated a fungal pathogen, *Ophidiomyces ophiodiicola* (formerly *Chrysosporium ophiodiicola*), but the causative agent has not yet been definitively identified. NWHC scientists are collaborating with the U.S. Fish and Wildlife Service, numerous state agencies, organizations, researchers, and other key stakeholders to investigate this potentially emerging disease and to learn more about its impacts on snake populations. For more information, visit http://www.nwhc.usgs.gov/disease_information/other_diseases/snake_fungal_disease.jsp.
Contact: Anne Ballmann, National Wildlife Health Center, 608-270-2445, aballmann@usgs.gov

Continued investigation of Newcastle Disease virus in cormorants in the Midwest
Newcastle Disease (ND) is a reportable disease in poultry and was last detected in U.S. poultry flocks in California in 2003. However, ND continues to cause mortality events in wild birds, particularly double-crested cormorants (*Phalacro coraxauritus*) (DCCO). The frequency of DCCO mortality events caused by Newcastle Disease virus (NDV) appears to be increasing in the Midwest with almost annual occurrence of NDV-associated mortality in DCCO in the Midwest since 2006 compared to the 11 year period between the first documented events in 1992 and second detection in 2003. Due to the apparent increase in frequency of NDV mortality events, scientists at the National Wildlife Health Center (NWHC) began a collaborative study to investigate the transmission dynamics of NDV in DCCO in 2012. Partners included in this project include the U.S. Department of Agriculture-Wildlife Services, Minnesota Department of Natural Resources, U.S. Fish and Wildlife Service, and the Leech Lake Band of Ojibwa. The study is focused primarily on determining the role of maternal antibodies in transmission of NDV. During 2012, over 1,000 adult and juvenile DCCO at several breeding colonies in Minnesota and Wisconsin were sampled for NDV. A NDV epizootic occurred on one of the study sites in 2012 that allowed scientists the opportunity to compare serology and virus isolation results at NDV outbreak and non-outbreak sites within the same year. Scientists on the project also assisted in the MN DNR's 2012 effort to control spread of this disease by performing carcass collection and incineration at several of the NDV outbreak sites in MN. During 2013, scientists will be focusing on DCCO breeding colonies in Minnesota where they again plan to collect over 1,000 samples from DCCO of various age classes. Understanding the role of maternal antibodies in the transmission dynamics of ND may help scientists predict future epizootic events in DCCO and develop disease management strategies.
Contact: LeAnn White, National Wildlife Health Center, 608-270-2491, clwhite@usgs.gov

Polar bears: Ongoing research into the cause and consequences of alopecia
In 2012, an alopecia (hair-loss) syndrome was observed in polar bears captured by the USGS during spring sampling of the southern Beaufort Sea subpopulation of Alaska. This was cause for concern given the earlier occurrence of a similar syndrome in ringed seals and Pacific walrus, which led the National Marine Fisheries Service and the U.S. Fish and Wildlife Service to declare an Unusual Mortality Event for northern pinnipeds in December of 2011. Since 2012, the Polar Bear Research Program has been working with the USGS National Wildlife Health Center and Alaska Veterinary Pathology Services to determine the cause and consequences of alopecia in polar bears. In 2013, alopecic bears were sampled in both the southern Beaufort and Chukchi Sea subpopulations. To date, the causative agent remains unknown, but analyses are ongoing. **Contact:** Tony DeGange, 907-786-7000, tdegange@usgs.gov

Polar bears as a sentinel for emerging zoonoses
Recently, the bacterium *Coxiella burnetii* was detected in polar bears for the first time by the USGS. The bacterium is the cause of Q-fever, which is capable of infecting both humans and animals, and its occurrence in polar bears marks a northward expansion within the marine ecosystem of the highly infectious pathogen's range. The presence of *Coxiella* and other zoonoses in the Arctic marine food web could represent a food-safety threat to subsistence hunters. The Polar Bear Research Program is working with specialists from Colorado State University, USDA Veterinary Services, and the Centers for Disease Control and Prevention to determine the risk of *Coxiella* and other pathogens (*Brucella spp.* and *Toxoplasma gondii*) to polar bears and humans. **Contact:** Tony DeGange, 907-786-7000, tdegange@usgs.gov

Avian influenza research and surveillance in wild birds of Alaska
The U.S. Geological Survey and the U.S. Fish and Wildlife Service in Alaska continue to summarize information collected during the intra-agency surveillance sampling for highly pathogenic H5N1 avian influenza that occurred from 2005-2010. Two new publications summarize new findings in the area of avian influenza seroprevalence in waterfowl and evidence that life history traits of waterfowl play a role in transmission dynamics of wild birds. **Contact:** Tony DeGange, 907-786-7000, tdegange@usgs.gov

Potential hot spot for avian flu transmission identified in western Alaska
The Yukon-Kuskokwim Delta is an important breeding ground for numerous birds and is located in an area where multiple migratory flyways converge, providing opportunities for infectious diseases, like avian influenza, to spread. In a paper recently published in the *Journal of Wildlife Diseases*, researchers

with the U.S. Geological Survey and the U.S. Fish and Wildlife Service describe results from the testing of over 24,000 samples from 82 species on the Yukon-Kuskokwim Delta from 2006 to 2009. The authors conclude that the study provides support for retaining the Yukon-Kuskokwim Delta as a high-priority region for the surveillance of potentially harmful avian pathogens. **Contact:** Tony DeGange, 907-786-7000, tdegange@usgs.gov

NPWRC American white pelican investigations

The USGS's National Wildlife Health Center (NWHC) and Northern Prairie Wildlife Research Center (NPWRC) worked cooperatively with three National Wildlife Refuges and State Waterfowl Management Areas investigating the impact of West Nile virus (WNV) on American white pelican colonies in northern Montana, North Dakota**,** and South Dakota. Research revealed that WNV caused significant mortality among pelican chicks at the northern plains colonies (Sovada et al. 2008, *Impact of West Nile virus and other mortality factors on American white pelicans at breeding colonies in the northern plains of North America*, Biological Conservation 141:1021–1031). In follow-up investigations, USGS scientists found that 1) virus was being shed by infected chicks, which could enable chick-to-chick transmission and help explain why WNV spreads rapidly in colonies, however viral titers were low; and 2) there was passive transfer of WNV antibody from female to chick. Investigative results indicated that WNV kills significant numbers of chicks that likely would fledge in the absence of WNV, that infection of chicks is pervasive, and that significant numbers of chicks survive infection (Sovada et al. 2013, *West Nile Virus in American White Pelican Chicks: Transmission, Immunity, and Survival*, American Journal of Tropical Medicine and Hygiene, 88:1152–1158).

Chronic wasting disease in elk at Wind Cave National Park, South Dakota

Chronic wasting disease (CWD) is a non-native, untreatable, and invariably fatal neurologic disease of cervids. The first documented case in South Dakota occurred in 1997, in a captive elk held adjacent to Wind Cave National Park (WICA). Subsequent discovery of CWD in a wild elk at WICA in 2001 led to suspension of translocations for population control, with uncertain implications for the growing elk population, which exceeded population objectives and was adversely affecting park vegetation and other wildlife. Since 2005, the USGS Survey Northern Prairie Wildlife Research Center and National Park Service have been studying dynamics and distribution of the population, with an emphasis on management implications of disease, predation, reduced recruitment, and seasonal movements. By 2005-2009, CWD had become a leading cause (3.4% annually; SE = 0.012) of mortality for elk at WICA and elk numbers were no longer increasing. Preliminary results of ongoing data collection suggest mortality rates have increased since 2009 and now exceed recruitment, although hunting mortality has declined and elk density in the park still exceeds objectives. Movement of elk out of the park could present an opportunity for non-lethal reduction of elk densities, but with uncertain implications for containment of CWD, which are a focus of our continuing work. **Contact**: Glen Sargeant, USGS Northern Prairie Wildlife Research Center, 701-253-5528, gsargeant@usgs.gov

Winter survey of bats in Washington Wildlife Refuges

Bats perform important functions in ecosystems, particularly by consuming large quantities of insects. Populations of some bat species are seriously threatened by white-nose syndrome (WNS), a fungal disease that is rapidly spreading southward and westward from where it was first detected in the northeastern United States. To develop a proactive strategy for management of WNS in the western states, managers need to know where bats are hibernating and which species are present. USGS scientist Joan Hagar and colleagues conducted acoustic and visual surveys of bats during the non-breeding season on national wildlife refuges in eastern Washington. The researchers found evidence of wintering bats at Columbia National Wildlife Refuge (NWR) and Little Pend Oreille NWR. They also identified two species of bat not previously found in the area in winter: California myotis and Townsend's big-eared bats. The study provides cursory bat distribution information to aid in conservation planning. The publication where these results are reported is available at http://pubs.usgs.gov/of/2013/1120/
Contact: Joan Hagar, FRESC, 541-750-0984, joan_hagar@usgs.gov

USGS assist in manatee captures in Mobile, Alabama

USGS biologists Jim Reid and Susan Butler participated in manatee captures in Mobile Bay, Alabama. Organized by Dauphin Island Sea Lab, these captures were conducted to enable radio tagging and health

assessment opportunities for Florida manatees in the western part of their range. Cooperators in the project also included Sea to Shore Alliance, SeaWorld Orlando, University of Florida, U.S. Fish and Wildlife Service and local volunteers. **Contact**: Jim Reid, 352-264-3546, jreid@usgs.gov

Salinity-based layering provided warmwater for manatees in severe winter of 2009-2010
A Marine Ecology Progress Series article coupled data taken during aerial surveys of live and dead manatees with hydrologic data from canal systems in the Ten Thousand Islands region during the extreme cold event of 2009-2010 winter to demonstrate that a halocline created warmwater pockets that provided a refugia for manatees. Although the halocline and warmwater manatee refugia had been previously described, the extreme nature of the 2009-2010 event demonstrated its ability to persist and protect manatees during extreme cold. The paper was published by USGS-SESC biologist Dr. Brad Stith (contracted by Cherokee Nation Technology Solutions), Dr. Dan Slone, Jim Reid, Dr. Catherine Langtimm (all SESC), Eric Swain, Lars Soderqvist, and partners from the Florida Fish and Wildlife Conservation Commission. **Contact**: Brad Stith, 352-264-3529, bstith@usgs.gov

Avian keratin disorder reveals novel pathology associated with beak deformities in black-capped chickadees
The U.S. Geological Survey with collaborators from the University of Minnesota and the University of Alaska Fairbanks have published a paper summarizing research prompted by a recent outbreak of beak deformities in wild birds in Alaska. The research investigated the gross, microscopic, and ultrastructural pathology of avian keratin disorder in Black-capped Chickadees. The lesions observed in affected chickadees were consistent with rapid production of keratin in the beak epidermis and included hyperplasia, hyperkeratosis, and disruption of the integrity of the cornified tissue. Claws showed similar changes, suggesting that multiple keratinized tissues are affected, but all other organs appeared normal. Bacterial or fungal pathogens are unlikely to explain the etiology of this disorder and additional study is needed to rule out a virus as a possible cause. The changes observed in affected birds did not correspond with any known avian diseases, suggesting a potentially novel hyperkeratotic disorder in wild birds.

> Van Hemert, C., A.G., Armien, J. E. Blake, C. M. Handel, T. M. O'Hara. In Press. Macroscopic, histologic, and ultrastructural lesions associated with avian keratin disorder in Black-Capped Chickadees (*Poecile atricapillus*). *Veterinary Pathology* 50 (3):500-13.

USGS work on recent manatee die-offs
There have recently been two unusual mortality events (UMEs) among Florida manatees in March 2013, including red-tide related deaths in Southwestern Florida and a lesser known die-off in Brevard County, Florida, in the vicinity of the Indian River lagoon (along Florida's Atlantic Coast). Although USGS Sirenia project often works with the state of Florida by assisting with necropsies during large-scale manatee die-offs, USGS has not been involved in helping with the current red tide event in Southwest Florida that has been in the news in recent days. However, USGS is working very closely with Florida Fish and Wildlife Conservation Commission to investigate manatee deaths in Brevard County. While these have received much less media attention, the cause remains poorly understood. State veterinarians have been unable to identify cause of death. USGS-SESC biologists have already been working with the state for the past four years on a manatee habitat use study in the region, which has involved monitoring movements of radiotagged manatees and identifying foraging areas. The research is investigating a possible link between the current manatee die-off and the superbloom of algae that began in 2011 and triggered high turbidity, therefore caused a dramatic die-off of submerged aquatic vegetation (SAV) in Indian River lagoon. Changes in manatee foraging strategies are being documented that may relate to the manatee mortality event. USGS-SESC researchers are proposing a study of stomach contents of the dead manatees to see if there are underlying organisms in the seagrass ecosystems that may be responsible for the deaths. Adding to concerns that a potential ecological disturbance has been the mechanism behind these unexplained deaths, Florida FWC has also put out a press release about unexplained pelican die-off in the same area. **Contact:** Jim Reid, 352-264-3546, jreid@usgs.gov

SESC samples record number of manatee in one day during winter health assessments
SESC scientists Bob Bonde, Cathy Beck, Maggie Hunter, Jim Reid, Susan Butler, and Gaia Meigs-Friend, along with USFWS Crystal River National Wildlife Refuge Manager Michael Lusk and staff,

international colleagues from the Bahamas, Brazil, Guadeloupe, and Singapore, biologists from the FWC, and veterinarians, researchers, and students from the University of Florida, conducted manatee health assessment captures in Crystal River on November 28 & 29, 2012. Sixteen healthy manatees, including a cow/calf pair, were captured using nets and monitored during the detailed biomedical assessments. Samples and biological data were collected. The nine manatees taken on the first day marks an all-time high for number of manatees processed during a single day. Weather conditions were ideal for this event and the team worked with great precision to expedite the handling and processing of these endangered manatees. **Contact**: Bob Bonde, 352-264-355, rbonde@usgs.gov

Manatee captures and health assessments in Brevard County, FL
SESC scientists Jim Reid, Susan Butler, Bob Bonde, Maggie Hunter, Amy Teague, and John Butterfield attended manatee captures in Brevard County as part of a cooperative effort with the Florida Fish and Wildlife Conservation Commission. This third year of the study is designed to monitor manatee habitat usage around the FPL (Florida Power & Light Company) power plant in Brevard County, Florida. Brevard County is a very important hub for manatee resources and provides habitat for a very large population of wintering, as well as summering manatees. The team captured 12 manatees in two days and fitted each of them with radio tracking devices. Detailed health assessments were also conducted on each of the manatees. All the manatees were in good physical condition, despite recent reductions in available seagrass throughout the Indian and Banana rivers. **Contact**: Bob Bonde, 352-264-355, rbonde@usgs.gov

SESC manatee health assessments in Crystal River, FL
SESC scientists Bob Bonde, Cathy Beck, Maggie Hunter, Jim Reid, Susan Butler, Amy Teague, Gaia Meigs-Friend, Michelle Davis, John Butterfield, and Gary Mahon, along with USFWS Crystal River National Wildlife Refuge Manager Michael Lusk and staff, biologists from the FWC, and veterinarians, researchers, and students from the University of Florida, conducted manatee health assessment captures in Crystal River on February 12 -13, 2013. Deb Epperson from BOEM also observed the event, with international scientist and managers from Canada, Brazil, Guadeloupe, and Puerto Rico. Seven manatees, including a large cow and her male calf, were captured using nets and monitored during the health assessment. Samples and biological data were collected on these endangered mammals. **Contact**: Bob Bonde, 352-264-355, rbonde@usgs.gov

New publication examines utility of different tissue types for detection and genetic characterization of blood parasites in Northern Pintail ducks
Blood parasites infect a wide range of avian species and may cause disease and/or influence breeding success. In a new publication, the U.S. Geological Survey in collaboration with the University of Georgia, describe the detection and genetic characterization of blood parasites from Northern Pintail ducks at important wintering areas for this species in the Pacific Americas flyway. The authors used samples from hunter-harvested birds collected over multiple years and determined that muscle tissue is useful for assessing parasite prevalence and that infection rates may vary between years. Genetic data indicate that parasites infecting northern pintails may not be host specific. Results demonstrate that blood parasites can be examined with sample types other than blood that are available through biopsy sampling, beached bird surveys, necropsies, or hunter harvest monitoring.

> Ramey, A.M. J.P. Fleskes, J.A. Schmutz, and M.J. Yabsley. 2013. Evaluation of blood and muscle tissues for molecular detection and characterization of haematozoa infections in northern pintails (*Anas acuta*) wintering in California. *International Journal of Parasitology: Parasites and Wildlife*, In Press.

New publication provides Evidence for Intercontinental Transport of Virus by Migratory Birds
Avian paramyxovirus serotype 1 (APMV-1) is the causative agent of Newcastle disease, one of the most economically important diseases for poultry production worldwide and a cause of periodic mortality events in wild birds in North America. In a new publication, scientists with the U.S. Geological Survey in collaboration with scientists from Japan, Russia, and elsewhere in the United States, describe the genetic diversity, mutation, and evidence for viral transport of APMV-1 in wild birds sampled in North America and Eurasia. The authors found previously undescribed viral diversity of APMV-1 and genetic analyses support the transport of APMV-1 between North America and Eurasia by migratory birds.

Ramey, A.M., A.B. Reeves, H. Ogawa, H.S. Ip, K. Imai, V.N. Gui, E. Yamaguchi, N.Y. Silko, and C.L. Alfonso. 2013. Genetic diversity and mutation of avian paramyxovirus serotype 1 (Newcastle disease virus) in wild birds and evidence for intercontinental spread. *Archives of Virology*, In Press.

Publications of interest – Disease Investigations

Ely, C.R., J.S. Hall, J.A. Schmutz, J.M. Pearce, J. Terenzi, J.S. Sedinger, and H.S. Ip. 2013. Evidence that life history characteristics of wild birds influence infection rates and exposure to influenza A viruses. *PLoS One* 8(3): e57614.

Reeves, A.B., J.M. Pearce, A.M. Ramey, C.R. Ely, J.A. Schmutz, P.L. Flint, D.V. Derksen, H.S. Ip, and K.A. Trust. 2013. Genomic analysis of avian influenza viruses from waterfowl in Western Alaska. *Journal of Wildlife Diseases* 49:600-610.

Wilson, H.M., J.S. Hall, P.L. Flint, J.C. Franson, C.R. Ely, J.A. Schmutz, and M.D. Samuel. 2013. High seroprevalence of antibodies to avian influenza among wild waterfowl in Alaska: implications for surveillance. *PLoS One* 8(3): e58308.

Amphibians

Efficacy of using a bacterial microbe as a strategy for resisting *Batrachochytrium dendrobatidis* infection in the Chiricahua leopard frog *(Rana chiricahuensis)*

The fungal disease chytridiomycosis is associated with recent, worldwide declines and extinctions of amphibians. The disease is prevalent in the southwestern United States and has affected Chiricahua leopard frog populations, especially in New Mexico. Currently listed as a threatened species, the leopard frog has disappeared from 75% of its historic range. Chytridiomycosis is often lethal, but some populations persist with the pathogen present. Previous work has suggested that a different frog species has a naturally-occurring skin bacterium that may provide resistance to the disease. Other studies have shown that exposing amphibians to this bacterium reduced the future incidence of infection. USGS scientists are studying whether application of this bacterium will be effective in preventing chytridiomycosis in the leopard frog. Results of the research may provide an option for wildlife managers to prevent infection and losses in captive or wild amphibians. **Contact**: Michael Adams, FRESC, 541-750-0980, mjadams@usgs.gov

Gonadal abnormalities in frogs (*Lithobates* spp.) collected from managed wetlands in an agricultural region of Nebraska, USA

Nebraska's Rainwater Basin wetland provides important habitat for North American migratory birds. Pesticide and nutrient runoff from surrounding row-crops enters wetlands and may degrade water quality and adversely affecting birds and wildlife. Frogs may be especially vulnerable. Researchers at the USGS Columbia Environmental Research Center conducted studies to evaluate Plains leopard frog metamorphs from the wetlands with varying concentrations of pesticides for a suite of biomarkers of exposure to endocrine active chemicals. Froglets had ovarian dysgenesis, high rates of testicular oocytes, and female-biased sex ratios, however there was no clear statistical association between pesticide concentrations and biomarkers. Emphasis is on describing the complex developmental biology of closely-related leopard frogs, how this understanding can explain Rainwater Basin anomalies, and the need for sampling at the appropriate life stage. Environmental Pollution: Volume 172, January 2013, Pages 1–8.

Contact Diana M. Papoulias, Columbia Environmental Research Center, dpapoulias@usgs.gov

New studies demonstrate indirect effects of climate change on status of amphibians

Three recent papers by USGS ecologists Susan Walls, William Barichivich, Mary Brown (all SESC) and Black Hossack (NOROC) reveal that climate change can affect wildlife populations indirectly, through hydrologic and ecological changes. They developed and tested models of how climate change in Florida was impacting the status and ecology of amphibians in this national biodiversity hotspot as part of their work for the USGS ARMI Program (Amphibian Research and Monitoring Initiative). Monitoring

revealed that amphibians in the Southeast are being affected by climatic extremes – severe droughts and 500+ year floods – which may influence the persistence of native amphibians. Related research revealed that a non-native, invasive species (Cuban treefrog) has a higher tolerance of saline habitats than native species, suggesting that, under scenarios of sea level rise and more intense tropical cyclones, climate change may facilitate its invasion into habitats previously occupied by native species. By combining rigorous monitoring data on species distributions in nature with focused research on the processes that may have contributed to these patterns, the science demonstrates how climate change impacts to amphibian life can be mediated by hydrologic and biological changes to ecosystem conditions.
Contact: Susan Walls, 352-264-3507, swalls@usgs.gov

Emerging ranavirus pathogens of lower vertebrates
Researchers from the Leetown Science Center have isolated largemouth bass virus from Northern snakehead (*Channa argus*), an invasive species inhabiting the Potomac River watershed. During a preliminary survey for introduced pathogens possibly harbored by these fish in Virginia waters, a filterable agent was isolated from five specimens that produced cytopathic effects in BF-2 cells. Based on PCR amplification and partial sequencing of the major capsid protein (MCP), DNA polymerase (DNApol) and DNA methyltransferase (Mtase) genes, the isolates were identified as largemouth bass virus (LMBV). Nucleotide sequences of the MCP (492 bp) and DNApol (419 pb) genes were 100% identical to those of LMBV. The nucleotide sequence of the Mtase (206 bp) gene was 99.5% identical with that of LMBV and the single nucleotide substitution did not lead to a predicted amino acid coding change. This is the first report of LMBV from the Northern snakehead, and evidence that non-Centrarchids may be susceptible to this virus.

> Iwanowicz , L., C. Densmore , C. Hahn , P. McAllister, J. Odenkirk. (2013) Identification of Largemouth Bass Virus in the Introduced Northern Snakehead Inhabiting the Chesapeake Bay Watershed, Journal of Aquatic Animal Health,25:3, 191-196.

Emerging ranaviruses of lower vertebrates investigation
Researchers at the Leetown Science Center are investigating the transmission and pathogenicity of ranaviruses as pathogens of lower vertebrates including many species of fish, amphibians, and reptiles. Comparative virulence of tadpole edema virus (TEV) among premetamorphic life stages of the Fowler's toad, a common anuran species, was examined through controlled aqueous viral challenge and quantal viral infectivity assays in a laboratory setting. Among the TEVchallenged groups, there was considerable variability in mortality and associated detection of virus among the life stages. Susceptibility appeared greatest during the periods of heightened physiological stress near hatch and metamorphosis. Investigators hve also reported isolation of a ranavirus closely related to Frog virus-3, the type species of ranavirus, from a juvenile painted turtle. Further work is underway to further distinguish this isolate from other ranaviruses and to evaluate its pathogenicity among lower vertebrates.

> Densmore, C. (2013) Susceptibility to the tadpole edema virus (TEV) among early life stages of the Fowler's Toad (Anaxyrus fowleri). 2nd International Symposium on Ranaviruses, July 27-29, 2013, Knoxville, TN.

> Iwanowicz, L., C Densmore, C Hahn. (2013) Isolation and partial sequencing of a FV-3-like ranavirus from the carcass of a juvenile eastern painted turtle (Chrysemys picta picta). 2nd International Symposium on Ranaviruses, July 27-29, 2013, Knoxville, TN.

Transcriptome resources for the frogs *Lithobates clamitans* and *Pseudacris regilla,* emphasizing antimicrobial peptides and conserved loci for phylogenetics
Researchers developed genetic resources for two North American frogs, Lithobates clamitans and Pseudacris regilla, widespread native amphibians that are potential indicator species of environmental and ecosystem health. For both species, mRNA from multiple tissues was sequenced using 454 technology. Because there is broad interest in amphibian immune factors, researchers manually annotated putative antimicrobial peptides. The results enable quick development of genetic markers for biomarker analysis including endocrine disruption and immune reactions. The results are also useful for phylogenetic studies of frogs, the taxonomy of which is poorly known.

Robertson, L. S. and R. S. Cornman, Molecular Ecology Resources, 2013 (In Press). Fish Health in Chesapeake Bay Tributaries: Associations with Pathogens, Parasites, LandUse and Water Quality

Smith, G.D., V.S. Blazer, H.L. Walsh, L.R. Iwanowicz, C. Starliper and A.J. Sperry. In Press. The effects of disease-related mortality on the recruitment of young-of-year smallmouth bass Micropterus dolomieu in the Susquehanna River basin, Pennsylvania. In: Tringali M.D., M.S. Allen, T. Birdsong, and J.M. Long (eds.). Black Bass Diversity: Multidisciplinary Science for Conservation. Proceedings of the Symposium Black Bass Diversity: Multidisciplinary Science for Conservation. American Fisheries Society, Bethesda, Maryland.

Starliper, C., V.S. Blazer, L.R. Iwanowicz and H.L. Walsh. In review. Bacterial isolates in diseased fishes, primarily smallmouth bass (Micropterus dolomieu), within the Chesapeake Bay drainage in 2009-2011. Proc. West Virginia Acad. Sci.

Walsh, H. L., V.S. Blazer, L.R. Iwanowicz and G. Smith. 2012. A redescription of Myxobolus inornatus from young-of-the-year Smallmouth Bass (Micropterus dolomieu). J. Parasitology 98:1236-1242.

Walsh, H. L., L.R. Iwanowicz, G. W. Glenney, D.D. Iwanowicz, and V.S. Blazer. 2012. Description of Two New Gill Myxozoans from Smallmouth (Micropterus dolomieu) and Largemouth (M. salmoides) Bass. J. Parasitology 98:415-422.

Fisheries

Postmortem analysis of ploidy of grass carp (*Ctenopharyngodon idella)* and black carp (*Mylopharyngodon piceus)*.
Habitat impacts from Asian carps can be substantial regardless of their ploidy status. Generally, diploid carp are capable of reproducing, while triploids have limited or no ability to reproduce. However, successful natural reproduction and persistence of nuisance Asian carp species is occurring in some North American waters. Protocols have been implemented for fisheries biologists to send feral caught Asian carp (eyeballs) samples for ploidy analysis by flow cytometry. Postmortem analysis is now possible, whereby live tissue up to two weeks postmortem or tissue frozen with cryoprotectant is used. Correct ploidy identification is allowing states to determine if diploids are in their waters or crossing state lines in hauling trucks, and the results are informing predictions of spread in watersheds. The Mississippi Interstate Cooperative Resource Association (http://www.micrarivers.org/) has distributed SOPS nationally, whereby relevant researchers, labs, and databases of feral captures are maintained and coordinated (e.g., http://nas.er.usgs.gov/; USGS Nuisance Aquatic Species database) and samples are being analyzed at Whitney Genetics Laboratory, Onalaska, Wisconsin (http://www.fws.gov/midwest/lacrossefishhealthcenter/) along with the eDNA surveillance program. **Contact:** J.A. Jenkins, USGS National Wetlands Research Center, jenkinsj@usgs.gov

Evaluation of sperm chromatin using preserved samples
Analysis of DNA parameters from male gametes and testicular tissue is typically done with freshly collected samples. A method developed using yellow perch, *Perca flavescens* allows the measurement of DNA quality in samples translocated over distance and time through a standard approach easily adapted for use with other species. Data can be obtained on DNA fragmentation, ploidy patterns reflecting spermatogenic stage (similar to histological staging), and chromatin compaction levels which reflects reproductive readiness. **Contact:** J.A. Jenkins, USGS National Wetlands Research Center, jenkinsj@usgs.gov

Emerging diseases of fish (WFRC)
Research by USGS Western Fisheries Research Center scientists, in collaboration with the University of Washington, Northwest Indian Fisheries Commission, Washington Department of Fish and Wildlife and the U.S. Department of Fish and Wildlife, has revealed a geographic range expansion of a highly virulent

fish virus in the coastal waters of Washington State. Infectious hematopoietic necrosis virus (IHNV) emerged from 2007 to 2011 and significantly impacted steelhead trout conservation programs in Coastal Washington State. This event affected seven different salmonid culture facilities in four different watersheds, and caused significant epidemic mortality in juvenile fish. Epidemiological analyses indicates that there were at least two separate introductions of IHNV into Coastal fish populations and that the most probable source of these introductions was the Columbia River Basin. **Contact**: Gael Kurath, Western Fisheries Research Center, gkurath@usgs.gov.

Viral hemorrhagic septicemia virus research
Researchers from the Western Fisheries Research Center, Marrowstone Marine Field Station recently described the transfer of viral hemorrhagic septicemia virus (VHSV) from Pacific herring to cultured Atlantic salmon. The results indicate that periodic epidemics of viral hemorrhagic septicemia (VHS) in the Atlantic salmon culture industry are likely initiated by exposure to waterborne virus that is shed by herring and other wild fishes in the NE Pacific. Avoiding VHS epidemics in Atlantic salmon farms would limit the potential of VHS in farmed Atlantic salmon, the possibility for further host adaptation in this species, and virus spillback to sympatric wild fishes. **Contact**: Paul Hershberger, Western Fisheries Research Center, phershberger@usgs.gov

Characterization of new and emerging viruses
USGS Western Fisheries Research Center scientists, in collaboration with others, have provided the initial characterization of several new or emerging viruses sent to the WFRC from federal, state, tribal, university and private sector laboratories for assistance in identifying the agent. These include: a series of aquareoviruses and paramyxoviruses from Pacific salmon, the hepatitis E virus-like cutthroat trout virus, as well as a nidovirus and several picornaviruses of minnows. **Contact**: Bill Batts, Western Fisheries Research Center, bbatts@usgs.gov

Immunology and caccinology of fish
The susceptibility and immune response of yellow perch after exposure to a highly virulent strain of viral hemorrhagic septicemia virus (VHSV) from the Great Lakes region studied by scientists from the School of Freshwater Sciences at the University of Wisconsin and USGS Western Fisheries Research Center.

The results demonstrated that some yellow perch stocks are more vulnerable to VHSV and that the virus employees various strategies to increase its replication within an infected host.
Contact: Evi Emmenegger, Western Fisheries Research Center, eemmenegger@usgs.gov

Efficacy of a DNA vaccine in Pacific herring study
Researchers at the Western Fisheries Research Center, Marrowstone Marine Field Station conducted a study on the efficacy of a DNA vaccine towards viral hemorrhagic septicemia (VHS) in Pacific herring. The disease is associated with population-level impacts throughout the NE Pacific, including Prince William Sound, where mortality from VHS and other diseases represents a leading hypothesis accounting for the decline and failed recovery of herring populations. **Contact:** Paul Hershberger, Western Fisheries Research Center, phershberger@usgs.gov

Basis of immunity study
USGS scientists at the Western Fisheries Research Center, in collaboration with other colleagues continue to study the basis of immunity in several species of fish. These studies have revealed key aspects of immune regulation in fish that can help to develop vaccines or other control strategies.
Contact: John Hansen, Western Fisheries Research Center, jhansen@usgs.gov.

Development and validation of diagnostic reagents and assays
USGS scientists at the Western Fisheries Research Center, in collaboration with the US Fish and Wildlife Service and Fisheries and Ocean Canada, have developed and validated a universal real-time PCR diagnostic assay for the salmonid fish pathogen, infectious hematopoietic necrosis virus (IHNV). The Western Fisheries Research Center serves as the international reference laboratory for IHNV by the World Organization for Animal Health (OIE) and validation of the test was conducted following the guidelines set forth by the OIE. The new test is currently being used in Canada as the primary screening test for IHNV, as part of their national fish pathogen surveillance program. In addition, several assays

were compared for the bacterial pathogen, *Renibacterium salmoninarum*, the causative agent of bacterial kidney disease (BKD). The WFRC also serves as the OIE Reference Laboratory for BKD. **Contact**: Diane Elliott or Maureen Purcell, Western Fisheries Research Center, delliott@usgs.gov or mpurcell@usgs.gov

Effects of temperature and climate change on fish diseases
USGS scientists at the Marrowstone Marine Field Station and Western Fisheries Research Center found that cool water temperature is one of the primary risk factors for viral hemorrhagic septicemia (VHS) susceptibility in marine fish. Epidemiological investigations of marine fish die-offs in British Columbia led to the hypothesis that cool water may be one factor associated with VHS epidemics. Controlled laboratory studies were used to demonstrate an inverse relationship between water temperature and VHS susceptibility of Pacific herring, evidenced by increased mortality, viral shedding and viral persistence in fish held at cooler temperatures. A recent review is in press outlining the potential impacts of climate change on infectious diseases in marine organisms, including fish. **Contact**: Paul Hershberger, Western Fisheries Research Center, phershberger@usgs.gov

Ichthyophonus research
Drs. Paul Hershberger, Diane Elliott and Maureen Purcell at the USGS Western Fisheries Research Center and Marrowstone Marine Field Station have been awarded a 2-year grant by the Arctic Yukon Kuskokwim Sustainable Salmon Initiative to conduct research on the fish parasite Ichthyophonus. This parasite has been hypothesized as a driver of long-term declines in Yukon River Chinook salmon by reducing spawning effectiveness and contributing to pre-spawning mortality due to the interactions of host, parasite, and environmental factors such as warming temperatures in the arctic that accelerate disease progression. **Contact**: Diane Elliott, Western Fisheries Research Center, delliott@usgs,gov

WFRC research on impacts of contaminants on fish diseases
Researchers at the USGS Western Fisheries Research Center, the USGS Columbia Environmental Research Center and the University of Washington have used a zebrafish exposure model and accompanying genomic resources to examine the impact of estradiols and cadmium on innate immunity; the first line of immunity for all vertebrates. Fish were exposed to environmental concentrations of 17a-ethinylestradiol or cadmium and then subjected to immune stimulation. Immune-relevant tissues were examined for differential gene expression using a genome-wide microarray for zebrafish. Two manuscripts are in final stages of preparation that show acute and sub-chronic exposures to 17a-ethinylestradiol and cadmium have adverse impacts on immune function thus impacting overall fish health. **Contact**: John Hansen, Western Fisheries Research Center, jhansen@usgs.gov

Marine fish diseases
Researchers from the Western Fisheries Research Center Marrowstone Marine Field Station continue to investigate the disease Viral Erythrocytic Necrosis (VEN). VEN is associated with intracytoplasmic inclusion bodies in red blood cells of affected fishes, and has been reported from more than 20 species of wild marine and anadromous fish worldwide. Mass mortalities periodically occur among Pacific herring populations in nearshore areas of the NE Pacific Ocean. **Contact**: Paul Hershberger, Western Fisheries Research Center, phershberger@usgs.gov

Viral hemorrhagic septicemia research
Researchers at the Western Fisheries Research Center Marrowstone Marine Field Station also described the course of viral hemorrhagic septicemia (VHS) in Pacific herring and investigated the impact of diet on progression of the disease. The disease is associated with population-level impacts throughout the NE Pacific, including Prince William Sound, where mortality from VHS and other diseases represents a leading hypothesis accounting for the decline and failed recovery of herring populations. **Contact**: Paul Hershberger, Western Fisheries Research Center, phershberger@usgs.gov

USGS study finds high extinction rates in North American fishes for past 110 years
Biologist Noel M. Burkhead (SESC) compared modern fish extinction rates (1900-2010) with extinction rates from the fossil record, using an established technique for assessing background extinction rates. By a conservative estimate, the modern extinction rate of North American freshwater fishes is 877 times

higher than the background extinction rate. The background rate has been one extinction every 3 million years, but between 1898-2006, 57 taxa became extinct. Since 1950s, the rate of extinction further increased, with 7.5 extinct taxa per decade. Reasonable estimates for future extinctions suggest that by 2050, a further 53-86 species may become extinct. **Contact**: Noel M. Burkhead, 352-264-3499, nburkhead@usgs.gov

Pathogens and diseases of fish

Myxobolus stanlii sp. n. was described from largescale stonerollers (Campostoma oligolepis) from the Mobile River Basin in Alabama. The parasite was described using critical identifying morphological features, and the 18S small subunit ribosomal RNA (SSU rRNA) gene sequence. The spore body was ovoid, 10.03 6 0.7 (7.5–11.0) lm long and 8.8 6 1.5 (6.3–11.3) lm wide in frontal view. Spore thickness was 6.3 6 2.7 (6.2–8.6) lm in sutural view. Polar capsules were pyriform, of equal size, and oriented in plane with the sutural ridge. Polar capsules were 2.45 6 1.5 (range 2.1–4.3) lm in width and 4.6 6 2.7 (range 4.5–6.9) lm in length. Based on the SSU rRNA gene sequence of Myxobolus stanlii sp. n. is most closely related to M. pseudodispar.

Iwanowicz, D. D., L.R. Iwanowicz, E.W. Howerth, W.B. Schill, V.S. Blazer, and R.L. Johnson. 2013. Characterization of a new Myxozoan Species (Myxozoa: Myxobolidae: Myxosporea) in Largescale Stonerollers (Campostoma oligolepis) from the Mobile River Basin (Alabama). Journal of Parasitology 99(1): 102-111.

A novel disease in North America: Swimbladder leiomyosarcoma in Atlantic Salmon (*Salmo salar*)

In cooperation with collaborators from Cornell University and the USFWS (Lamar, PA and North Attleboro, MA) leiomyosarcoma was described associated with a retrovirus that was found for the first time in North America among adult Atlantic salmon (Salmo salar) held in a quarantine facility at the North Attleboro National Fish Hatchery (NANFH), Massachusetts. The fish had been collected as age 1–2 yr animals from the Pleasant River, Maine, and were to be used as brood stock in a population augmentation program for that river. Neoplastic disease was observed at NANFH initially in older (age 4 yr) fish, followed by age 3 yr fish. Disease was not observed in age 2 yr fish. The mortality was chronic in nature.

Paul R. Bowser, James W. Casey, Rufina N. Casey, Sandra L. Quackenbush, Larry Lofton, John A.Coll, and Rocco C. Cipriano. 2012. Swimbladder Leiomyosarcoma in Atlantic Salmon (Salmo salar) in North America. Journal of Wildlife Diseases, 48(3), 2012, pp. 537-541.

Comparative analysis of Edwardsiella isolates from fish in the eastern United States identifies two distinct genetic taxa

In collaboration with researchers at Mississippi State University and in response to the Southeastern U. S. Cooperative Fish Disease Project, the fish pathogen, Edwardsiella tarda, a Gram-negative member of the family Enterobacteriaceae, was assessed for intra-specific variability from 4 different fish species in the eastern United States. Repetitive sequence mediated PCR (rep-PCR) using 4 different primer sets (ERIC I & II, ERIC II, BOX, and GTG5) and multi-locus sequence analysis of 16S SSU rDNA, groEl, gyrA, gyrB, pho, pgi, pgm, and rpoA gene fragments identified two distinct genotypes (DNA group I; DNA group II). Conventional PCR analysis using published E. tardaspecific primer sets yielded variable results, with several primer sets producing no observable amplification of target DNA from some isolates. Fluorometric determination of G + C content demonstrated 56.4% G + C content for DNA group I, 60.2% for DNA group II, and 58.4% for E. ictaluri. Surprisingly, these isolates were indistinguishable using conventional biochemistry. Analysis using two commercial test kits identified multiple phenotypes, although no single metabolic characteristic could reliably discriminate between genetic groups. Additionally, anti-microbial susceptibility and fatty acid profiles did not demonstrate remarkable differences between groups. The significant genetic variation (<90% similarity at gyrA, gyrB, pho, phi and pgm; <40% similarity by rep-PCR) between these groups suggests organisms from DNA group II may represent an unrecognized, genetically distinct taxa of Edwardsiella that is phenotypically indistinguishable from E. tarda.

Griffin, M.J., S M Quiniou, T Cody, M Tabuchi, C Ware, R C. Cipriano, M J. Mauel, and E Soto. 2013. Comparative analysis of Edwardsiella isolates from fish in theeastern United States identifies two distinct genetic taxa amongst organisms phenotypically classified as E. tarda. Veterinary Microbiology 165: 358–372

Polyphasic characterizations of Aeromonas salmonicida isolates from Great Lakes fishes
In collaboration with researchers at Michigan State University and the Great Lakes Fishery Commission, the prevalence of A. salmonicida was determined for six species of Michigan's Great Lakes fishes. Bacterial isolates were characterized by biochemical and gene sequence analyses. A total of 2,202 wild, feral, and hatchery-propagated fish were examined, which included Chinook salmon, Oncorhynchus tshawytscha, (coho salmon, O. kisutcha, steelhead trout, O. mykiss, Atlantic salmon, Salmo salar, brook trout, Salvelinus fontinalis, and yellow perch, Perca flavescens. Among these, 234 fish yielded positive results for presumptive A. salmonicida infection. Further phenotypic and phylogenetic analyses identified representative isolates as Aeromonas salmonicida subsp. salmonicida and revealed some genetic, though hitherto unreport, and biochemical variability. Logistic regression analyses showed that infection prevalences varied according to host fish species and even different strains of the same species. Prevalence estimates were also affected by year and gender, whereby Chinook salmon (20.5%) and females (26%) had significantly highest prevalence of infection, as compared to steelhead (0.8%) and males (8.25%), which had the lowest prevalences.

Diamanka, A. , T. Loch, R. Cipriano, and M. Faisal. Polyphasic Characterization of Aeromonas salmonicida Isolates Recovered from Salmonid and Non-Salmonid Fishes. Article first published online: 27 FEB 2013 DOI: 10.1111/jfd.12092.

Bactericidal efficacy of elevated pH on fish pathogenic and environmental bacteria
Investigators at the Leetown Science Center completed a study investigating the morphological and physiological effects of electrofishing on target and by-catch species common to coldwater Appalachian streams. In laboratory trials using a standard electrofishing methodology (one, two, or three electroshocks with100-V, 60-Hz or 200-V 30 Hz pulsed DC), the incidence and severity of trauma associated with multiple-pass electrofishing and the effects on short-term (30-d) survival and growth of rainbow trout (Oncorhynchus mykiss), brook trout (Salvelinus fontinalis), and five representative co-inhabiting nontarget or bycatch species were examined. Physiological indicators of stress and trauma including blood glucose, lactate, and other blood chemistry parameters were likewise evaluated. Significant relationships between the number of electrical shocks and the frequency and severity of hemorrhagic and spinal trauma were evident in each of the nontarget species, including Potomac sculpin (Cottus girardi), channel catfish (Ictalurus punctatus), fathead minnow (Pimephales promelas), green sunfish (Lepomis cyanellus), and largemouth bass (Micropterus salmoides). All species demonstrated physiological responses to PDC electroshock, with or without gross evidence of hemorrhagic trauma, and serum lactate was the most consistent indicator of these effects. There were no significant differences in 30-d postshock condition factors despite observations of altered feeding behavior lasting several days to 1week posttreatment in several of the study species. There was also no apparent link between the altered blood chemistry and increased mortality 30 d post electroshock.

Densmore, C.L., F.M. Panek (2013). Effects of Depletion Sampling by Standard Three-Pass Pulsed DC Electrofishing on Blood Chemistry Parameters of Fishes from Appalachian Streams, North American Journal of Fisheries Management, 33:2, 298-306

Panek, F.M., C.L. Densmore (2013). Frequency and Severity of Trauma in Fishes Subjected to Multiple-Pass Depletion Electrofishing, North American Journal of Fisheries Management, 33:1, 178-185.

Starliper, Clifford E.; Watten, Barnaby J., Journal of Advanced Research, 4: 345 – 353, 2013

Adapting metabolomic profiles to assessments of fish health
In a collaborative effort between the USGS/NFHRL, USFWS/Region 5, and personnel at Georgia Tech and the Georgia Aquarium, metabolomic assays were adapted for assessments of fish health on two cohort populations of 4-5 year old Atlantic salmon (*Salmo salar*). Sea-run migrants were sampled upon

their return to the Connecticut River after being held for 7-months prior to spawn at the Richard Cronin National Salmon Station (Sunderland, MA). Throughout their migration off the coast of Greenland until they spawn, these fish are inappetent. Cohorts of this population, domesticated at the White River National Fish Hatchery (Bethel, VT, were also assayed. Those fish continue to feed up to and through their spawning cycle. Forty plasma samples were collected in December (2011) from each population post-spawn. Samples were processed for chromatography and spectrometry and Principal Component Analysis was used to evaluate differences, as well as to identify those metabolites that accounted for significant differences between the two groups. A statistically significant delineation was observed between the two groups of Atlantic salmon cohorts with one exception. In that instance, one of the domestic fish clustered closely with the sea-run cohorts. Such discrimination was a function of 61 metabolites expressed among 23 biochemical pathways. The most significant differences were noted in unsaturated fatty acid synthesis. This involved the two essential omega-3 fatty acids (Timnodonic and Cervonic Acids) and the omega-9, Gondoic Acid. Though was also a consistent depletion of all three of the branched chain amino acids (valine, isoleucine and leucine) among the sea-run fish, although valine was the only BCAA that was significantly different between the two groups. Nothing dysfunctional was apparent between the feeding versus the non-feeding fish; - their metabolomic profiles were just different. As inappetence is part of the natural life cycle for migrating Atlantic salmon, it seems that the species has evolved a somewhat "normal" physiological manner for something that we would otherwise consider an abnormal (non-feeding) behavior. Manuscript in preparation.

Chesapeake watershed and skin lesions in centrarchids and sucker species

Research by USGS Leetown Science Center, Fish Health Branch, scientists, in collaboration with the West Virginia and Pennsylvania Cooperative Fish and Wildlife Units, Fish and Wildlife Service, WV Departments of Natural Resources and Environmental Protection, Maryland Department of Natural Resources, PA Fish and Boat Commission, PA Dept. of Environmental Protection and non-profit organizations, has addressed a variety of fish health issues within the Chesapeake watershed for many years. Most recently this research has focused on the high incidence of skin lesions in centrarchids and sucker species, spring mortalities of adult fish and summer mortalities of young-of-year smallmouth bass. Numerous infectious agents (bacteria, viral), although none consistently, are observed, indicating immunosuppression of sensitive species. New species of gill myxozoan parasites have been described that may contribute to the mortalities of adult bass. A myxozoan parasite has been implicated in the young-of-year mortalities. Current studies are directed toward identifying the intermediate host, as well as factors associated with transmission of this parasite. There is evidence these disease problems are having population effects in some areas. Ongoing collaborative studies are addressing risk factors for disease outbreaks, including nutrients, chemical contaminants, climatic factors, algal toxins, invasive species and associated land-use.

Development of biological effect-based tools for monitoring fish health

Aquatic organisms are constantly exposed to complex mixtures of both legacy and contaminants of emerging concern. These complex mixtures can have additive, as well as synergist and antagonists effects. In addition, it is increasingly recognized that many chemicals, particularly those influencing the endocrine and immune systems, may not elicit the typical dose response curves. Hence, biological effects-based monitoring is increasingly recognized as an important factor in assessing the effects of toxic chemicals and other stressors on ecosystem health. Biological indicators of degraded ecosystems, such as increased infectious disease and certain parasite infections, skin lesions, unusual mortality, poor recruitment/reproductive success, tumors, feminization of male fishes and other signs of endocrine disruption are difficult to associate with one cause. There is a need to develop tools to assess adverse effects, demonstrate mechanisms of action and indicate potential causes/contributing factors. Researchers at the Leetown Science Center, Fish Health Branch, are collaborating with the Fish and Wildlife Service, Environmental Protection Agency, WV Cooperative Fish and Wildlife Unit, Carnegie Institute, University of Alabama at Birmingham, National Cancer Institute, in the development and field validation of both in vitro and in vivo assays. Landuse analysis approaches are integrated as well as models for predictive approaches.

Ciparis, S., Iwanowicz, L.R., Voshell, J.R. 2012. Effect of watershed densities of animal feeding operations on nutrient concentrations and estrogenic activity in agricultural streams. Science of the Total Environment 414: 268-276.

Gorelick, D.A., L.R. Iwanowicz, A.L. Hung, V.S. Blazer and M.E. Halpern. In Press. Endocrine disrupting compounds reveal tissue-specific differences in estrogen receptor activation. Environ Health Perspect.

Ekman, D.R., G.T. Ankley, V.S. Blazer, T.W. Collette, N. Garcia-Reyero, L.R. Iwanowicz, Z. Jorgeson, K. Lee, P.M. Mazik, D. Miller, E.J. Perkins, E. Smith, J. Tietge, A. Trowbridge and D.L. Villeneuve. In Press. Biological effects-based tools for monitoring impacted surface water in the Great Lakes: A multiagency research program in support of the GLRI. Environmental Practice.

Stavreva, D.A., A.A. George, P. Klausmeyer, D. Sack, L. Varticovski, R.L. Schiltz, T.C. Voss, V.S. Blazer, L.R. Iwanowicz and G.L. Hager. 2012. Contamination of water sources in the US with biologically active glucocorticoids and androgens. Nature Scientific Reports 2:937; DOI:10.1038/srep00937.

Shenandoah Rivers, USA, water research

Fish Tumors and Indicators of Contaminant Exposure at Great Lakes Areas of Concern Researchers at the Leetown Science Center, Fish Health Branch, are collaborating with the WV Cooperative Fish and Wildlife Unit, West Virginia University, Fish and Wildlife Service, Environmental Protection Agency, Wisconsin Department of Natural Resources, University of Wisconsin, Minnesota Pollution Control Board and Ohio Environmental Protection Agency to assess tumors and other indicators of exposure to contaminants at Great Lakes Areas of Concern. Areas of Concern are designated due to impairments of beneficial uses and include “fish tumors or other deformities”. The extant tumor prevalence is necessary to determine whether specific Areas can be delisted. Current monitoring is addressing the prevalence or skin and liver tumors and preneoplastic changes at Areas of Concern on Lakes Erie, Ontario, Michigan and Superior. Risk factors such as contaminants, viruses and parasites are being investigated using histopathology and molecular analyses. In addition, stable isotopes were used in the St. Louis River system to identify specific areas of the river associated with a higher risk of skin neoplasia. Further studies are underway to utilize this methodology to better understand fish health issues.

Blazer, V.S., J. Hoffman, H.L. Walsh, R.P. Braham, C. Hahn, P. Collins, Z. Jorgenson and T. Ledder. In Review. Fish health associated with habitat usage in the St. Louis River Area of Concern, Minnesota USA. Ecotoxicology

Publications of interest – Fisheries

Batts, W.N., A.E. Goodwin and J.R. Winton. 2012. Genetic analysis of a novel nidovirus from fathead minnows. Journal of General Virology 93:1247-1252.

Beaulaurier, J., N. Bickford, J.L. Gregg, C.A. Grady, A. Gannam, J.R. Winton and P.K. Hershberger. 2012. Susceptibility of Pacific herring to viral hemorrhagic septicemia is influenced by diet. Journal of Aquatic Animal Health 24:43-48.

Breyta, R., A. Jones, B. Stewart, R. Brunson, J. Thomas, J. Kerwin and G. Kurath. in press. Emergence of MD type infectious hematopoietic necrosis virus in Washington coastal steelhead trout. Diseases of Aquatic Organisms

Burge, C.A., C.M. Eakin, C.S. Friedman, B. Froelich, P.K. Hershberger, E.E. Hofmann, L.E. Petes, K.C. Prager, E. Weil, B.L. Willis and C.D. Harvell. in review. Climate change impacts on marine infectious diseases: Implications for management and society. Annual Review of Marine Sciences

Debing, Y., J. Winton, J. Neyts and K. Dallmeier. in press. Cutthroat trout virus as a convenient surrogate in vitro infection model for testing inhibitors of hepatitis E virus replication. Antiviral Research

Elliott, D.G., L.J. Applegate, A.L. Murray, M.K. Purcell and C.L. McKibben. 2013. Bench-top validation testing of selected immunological and molecular *Renibacterium salmoninarum* diagnostic assays by comparison with quantitative bacteriological culture. Journal of Fish Diseases doi: 10.1111/jfd.12079

Glenn, J.A., E.J. Emmenegger, C.A. Grady, S.R. Roon, J.L. Gregg, C.M. Conway, J.R. Winton and P.K. Hershberger. 2012. Kinetics of viral load and erythrocytic inclusion body formation in Pacific herring artificially infected with erythrocytic necrosis virus. Journal of Aquatic Animal Health 24:195-200.

Hansen, J.D., J.C. Woodson, P.K. Hershberger, C. Grady, J.L. Gregg and M.K. Purcell. 2012. Induction of anti-viral genes during acute infection with *Viral hemorrhagic septicemia virus* (VHSV) genogroup IVa in Pacific herring (*Clupea pallasii*). Fish and Shellfish Immunology 32:259-267.

Hart, L.M., N. Lorenzen, S.E. LaPatra, C.A. Grady, S.E. Roon, J. O'Reilly, J.L. Gregg and P.K. Hershberger. 2012. Efficacy of a glycoprotein DNA vaccine against viral hemorrhagic septicemia (VHS) in Pacific herring *Clupea pallasii* Valenciennes. Journal of Fish Diseases 35:775-779.

Hershberger, P.K., M.K. Purcell, L.M. Hart, J.L. Gregg, R.L. Thompson, K.A. Garver and J.R. Winton. 2013. Influence of temperature on viral hemorrhagic septicemia (Genogroup Iva) in Pacific herring, *Clupea pallasii* Valeciennes. Journal of Experimental Marine Biology and Ecology 44: 81-86.

Lovy, J., P. Piesik, P.K. Hershberger and K.A. Garver. in review. Experimental infection studies demonstrating Atlantic salmon as a host and reservoir of viral hemorrhagic septicemia virus type Iva with insights into pathology and host immunity. Veterinary Microbiology

Lovy, J., N.L. Lewis, P.K. Hershberger, W. Bennett and K.A. Garver. 2012. Viral tropism and pathology associated with viral hemorrhagic septicemia in larval and juvenile Pacific herring. Veterinary Microbiology 161: 66-76.

Olson, W., E. Emmenegger, J. Glenn, J. Winton and F. Goetz. in press. Comparative susceptibility among three stocks of yellow perch (*Perca flavescens*) to Great Lakes Viral Hemorrhagic Septicemia Virus IVb. Journal of Fish Diseases.

Olson, W., E. Emmenegger, J. Glenn, C. Simchick, J. Winton and F. Goetz. 2013. Expression kinetics of key genes in the early innate immune response to Great Lakes viral hemorrhagic septicemia virus IVb infection in yellow perch (*Perca flavescens*). Developmental and Comparative Immunology 41:11-19.

Phillips, R.B., J.J. deKoning, J.P. Brunelli, J.J. Faber-Hammond, J.D. Hansen, K.A. Christensen, S.C.P. Renn and G.H. Thorgaard. 2013. Characterization of the OmyY1 region on the rainbow trout Y chromosome. International Journal of Genomics Article ID 261730, 10pp.

Purcell, M.K., E.S. Bromage, J. Silva, J.D. Hansen, S.M. Badil, J.C. Woodson and P.K. Hershberger. 2012. Production and characterization of monoclonal antibodies to IgM of Pacific herring (*Clupea pallasii*). Fish and Shellfish Immunology 33:552-558.

Purcell, M.K., K.J. Laing and J.R.Winton. 2012. Immunity to fish rhabdoviruses. Viruses 4:140-166.

Purcell, M.K., R.L. Thompson, K.A. Garver, L.M. Hawley, W.N. Batts, L. Sprague and J.R. Winton. in press. Development and validation of a universal reverse-transcriptase real-time PCR for infectious hematopoietic necrosis virus (IHNV).

Ramirez-Gomez, F., W. Greene, K. Rego, J.D. Hansen, G. Costa, P. Katrina and E.S. Bromage. 2012. Discovery and characterization of secretory IgD in rainbow trout: Secretory IgD is produced through a novel splicing mechanism. Journal of Immunology 188:1341-1349.

Vojtech, L.N., N. Scharping, Woodson, J.C. and J.D. Hansen. 2012. Roles of inflammatory caspases during processing of interleukin-1B in *Francisella noatunensis* infection. Infection and Immunity 80: 2878-85.

Contaminants

Heavy metal accumulation in Arizona investigation
The USGS SBSC investigated the distribution and cascading extent of heavy metal accumulation in Song Sparrows (*Melospiza melodia*, a resident riparian species) in Arizona's upper Santa Cruz River watershed. This study had three goals: 1) quantify the degree of heavy metal accumulation in sparrows and determine the distributional patterns among study sites, 2) compare concentrations of metals found in this study to those found in studies performed prior to a wastewater facility upgrade, and 3) assess the condition of Song Sparrows among sites with differing potential levels of exposure. Six focal study sites that reflected different potential sources of contamination were examined. Body mass residuals and leukocyte counts were used to assess sparrow condition. Eight metals in blood and feathers showed significant patterns in abundance among sites. Cadmium, copper, mercury, nickel, and selenium exceeded background levels at some sites, but were generally lower than or similar to earlier studies performed prior to the international sewage treatment plant upgrade. Recaptured birds showed higher concentrations in 2012 than 2011 for two and five metals in blood and feathers, respectively, suggesting possible bioaccumulation. There were no cascading effects as a result of metal exposure found but metal levels were significantly reduced following the Nogales international wastewater treatment plant upgrade. **Contact:** Charles van Riper III, Southwest Biological Science Center, 520-626- 7027, charlesvanriper@usgs.gov

Birds as indicators of contaminant exposure and effects in the Great Lakes
Historical (e.g., organochlorine insecticides, polychlorinated biphenyls [PCBs], dioxins, mercury, polycyclic aromatic hydrocarbons) and newly emerging contaminants (e.g., perfluorinated compounds [PFCs], and flame retardants [PBDEs]) are distributed throughout the Great Lakes and were found at exceptionally high levels at some Areas of Concern (AOCs). Significant concerns still exist related to the exposure of biological populations and food webs to these contaminants, and to the possible adverse effects on their survivorship and metabolism. USGS scientists at the Upper Midwest Environmental Sciences Center (UMESC) are utilizing funding through the Great Lakes Restoration Initiative (GLRI) to sample select species of birds (tree swallows and colonial waterbirds) at over 40 sites across all five Great Lakes as indicators of chemical contamination exposure and effects on the avian community. Emphasis is on both newly emerging (e.g., PFCs and PBDEs) and legacy contaminants (e.g., PCBs and mercury). Special emphasis is being placed on areas of remediation and wastewater treatment plants. The study sites and data collection dovetail with other GLRI projects of the U.S. Fish and Wildlife Service, with the GLRI enhanced Mussel Watch Program of the National Oceanic and Atmospheric Administration (NOAA), and with existing programs of the Environmental Protection Agency (EPA). Changes in chemistry and biological indicators relative to avian samples are being used to interpret the success of remediation activities already completed or in progress. The exposure and effect studies will provide important data for EPA and State regulators to use in determining the degree of beneficial use impairments (BUI) including reproductive effects and adverse impacts to fish and wildlife populations. Because of this, these data will contribute to BUI assessments and potentially AOC delisting. Current results can be found at http://www.umesc.usgs.gov/wildlife_toxicology/glri_project80.html.
Contact: Thomas W. Custer, Upper Midwest Environmental Sciences Center, 608-781-6375, tcuster@usgs.gov.

Immunological and reproductive health assessment in herring gulls and black-crowned night herons in the Hudson–Raritan Estuary
Researchers at the USGS Columbia Environmental Research Center collaborated with Calvin College Grand Rapids, Michigan to study relationships of contaminants in the 1996-2002 decline of breeding waterbird populations within western New York/New Jersey Harbor. The study assessed associations between immune function, prefledgling survival, and polychlorinated dibenzo-*p*-dioxins, polychlorinated biphenyls (PCBs) and metals in herring gulls and black-crowned night herons in lower New York Harbor during 2003. Strong negative correlations between the T cell function response and dioxins and PCBs in gull livers was strong evidence suggesting that these chemicals contributed significantly to

immunosuppression in New York Harbor waterbirds. Grasman et al: Environmental Toxicology and Chemistry, Feb. 2013, 32: 548–561, **Contact** Kathy Echols, Columbia Environmental Research Center.

Toxicity of sediments potentially contaminated by coal mining and natural gas extraction to unionid mussels and commonly tested benthic invertebrates

Researchers at the USGS Columbia Environmental Research Center conducted sediment toxicity tests to assess potential effects of contaminants associated with coal mining or natural gas extraction activities in the upper Tennessee River basin and eastern Cumberland River basin in the United States. Test species included two unionid mussels (rainbow mussel and wavy-rayed lampmussel, 28-d exposures), and the commonly tested amphipod, *Hyalella azteca* (28-d exposure) and midge, *Chironomus dilutus* (10-d exposure). Results indicated that (1) the findings from laboratory tests were generally consistent with the field observations of adverse impacts on mussel populations; (2) total recoverable metals, PAHs, or major ions, or all three in sediments might have contributed to the sediment toxicity; (3) the mussels were more sensitive to the contaminants in sediments than the amphipod and midge; and (4) a sediment toxicity benchmark of 1.0 based on Probable Effects Concentrations may not be protective of mussels. Environmental Toxicology and Chemistry 32(1): 207-221, (91922) **Contact:** Ning Wang, Columbia Environmental Research Center, nwang@usgs.gov

Effects of historical lead–zinc mining on riffle-dwelling benthic fish and crayfish in the Big River of southeastern Missouri, USA

The Big River drains much of the Old Lead Belt mining district in southeastern Missouri, USA, which was historically among the largest producers of lead–zinc (Pb–Zn) ore in the world. Researchers at the USGS Columbia Environmental Research Center sampled benthic fish and crayfish in riffle habitats at eight sites in the Big River and conducted 56-day in situ exposures to the woodland crayfish and golden crayfish in cages at four sites affected by differing degrees by mining. Metals (lead, zinc, cadmium) concentrations were greater at mining and downstream sites than at reference sites. Fish and crayfish densities were significantly greater at reference than mining or downstream sites, and densities were greater at downstream than mining sites. Survival of caged crayfish was significantly lower at mining sites than reference sites; downstream sites were not tested. Chronic toxic-unit scores and sediment probable effects quotients indicated significant risk of toxicity to fish and crayfish, and metals concentrations in crayfish were sufficiently high to represent a risk to wildlife at mining and downstream sites. Collectively, the results provided direct evidence that metals associated with historical mining activities in the Old Lead Belt continue to affect aquatic life in the Big River. Ecotoxicology (2013) 22:506-521, (91931). **Contact**: Ann Allert, Columbia Environmental Research Center, aallert@usgs.gov

Contaminants in stream sediments from seven United States metropolitan areas: Part II—sediment toxicity to the amphipod Hyalella azteca and the midge Chironomus dilutus

Researchers at the USGS Columbia Environmental Research Center, Georgia Water Science Center (WSC), California WSC, Washington WSC and the University of Guelph Canada, evaluated relationships between sediment toxicity and sediment chemistry for 98 samples collected from seven metropolitan study areas across the United States. Sediment-toxicity tests were conducted with the amphipod *Hyalella azteca* (28 day exposures) and with the midge *Chironomus dilutus* (10 day exposures). Overall, 33 % of the samples were toxic to amphipods and 12 % of the samples were toxic to midge based on comparisons with reference conditions within each study area. Archives of Environmental Contamination and Toxicology 64(1): 52-64, (91927). **Contact:** Nile Kemble, Columbia Environmental Research Center, nkemble@usgs.gov

Forest structure, water chemistry influence fish mercury concentration in high-elevation lakes

Mercury is a globally distributed, toxic environmental contaminant that reaches even remote, high-elevation lakes through atmospheric deposition. Mercury's ecological risk depends on complex environmental processes that make it available to accumulate up food chains, into fish. Researchers from the USGS and U.S. Forest Service surveyed 28 high-elevation lakes in Oregon to assess mercury bioaccumulation in fish. Mercury concentrations in fish varied up to 18-fold across the lakes sampled, even though many lakes were in close proximity to one another. The most important factors driving fish

mercury concentration were the density of conifer trees in lake basins, lake surface area, and water chemistry. Only 1 of 327 fish sampled exceeded the U.S. Environmental Protection Agency's limit for human mercury consumption, but many fish contained levels of mercury considered detrimental to fish-eating wildlife. These results suggest that options exist at several spatial scales to address mercury contamination in lakes. The publication reporting these results is available at http://pubs.usgs.gov/of/2013/1148/ **Contact**: Collin Eagles-Smith, FRESC, 541-750-0949, ceagles-smith@usgs.gov

Different factors influence mercury exposure in wading birds

Mercury is a pervasive contaminant that can lead to reproductive and hormonal impairment in waterbirds. Complex environmental processes influence how and where wildlife might be exposed to mercury. USGS scientists and collaborators examined how local conditions and landscape context in the Florida Everglades influenced mercury exposure in great egrets and white ibises, two wading-bird species with different foraging behaviors. The researchers found that separate factors affected mercury concentrations in each of the two species, stemming from how they fed. Mercury in blood of roaming, generalist egrets was unaffected by detailed characteristics of its feeding areas and primarily dictated by the broad region they occupied. In ibises, which were more selective and foraged in drying wetland pools, mercury bioaccumulation was most influenced by the duration that ibis feeding sites remained dry the previous year. These results can contribute to wetland management strategies for reducing mercury exposure in waterbirds. The publication describing this research is available at http://www.sciencedirect.com/science/article/pii/S0048969713004580 **Contact**: Collin Eagles-Smith, FRESC, 541-750-0949, ceagles-smith@usgs.gov

Tracking nitrate movement from soils to streams

Nitrogen is an essential nutrient for plant growth, yet in large quantities as nitrate can also be an environmental contaminant that degrades water quality. USGS ecologist Steve Perakis and colleagues examined data from 62 watersheds to assess whether nitrate levels in stream waters reflected nitrate levels measured in soil water of upland ecosystems. In watersheds covered by natural vegetation, nitrate levels in soil and stream waters were closely related, with about half of the nitrate removed before reaching streams. However, in urban and agricultural watersheds, a larger fraction of nitrate reached streams.

These results suggest that human alteration of watersheds, possibly related to changes in riparian zones that border streams, can decrease the efficiency of nitrate removal before it reaches streams. The abstract of the publication describing this research is available at http://onlinelibrary.wiley.com/doi/10.1002/jgrg.20030/abstract **Contact**: Steven Perakis, FRESC, 541-750-0991, sperakis@usgs.gov

Contaminant exposure and stress in avian scavengers

The U.S. Fish and Wildlife Service and the Condor Recovery Program are evaluating the possible reintroduction of endangered California condors into Oregon and Washington, a portion of their historic range. Potential threats must first be examined, including the risk of condor exposure to contaminants, which may affect reproduction and adult survival. Evaluating these threats is challenging because the birds require an expansive home range where they feed on large terrestrial and marine carcasses. A new USGS study, in collaboration with the nonprofit group Coastal Raptors, will measure levels of mercury and lead in blood and feathers of three other avian scavengers (turkey vulture, bald eagle, and common raven) to study potential exposure pathways in condors. Researchers also plan to measure levels of corticosterone, a stress-produced hormone, to assess the birds' physiological response to contaminants. Results will have important implications for the successful reintroduction of the California condor. **Contact**: Collin Eagles-Smith, FRESC, 541-750-0949, ceagles-smith@usgs.gov

Amphibians: Mercury risk and effects of non-native fish in Olympic National Park

Mercury contamination and non-native species invasions are two priority threats to ecological function. Importantly, each of these threats can exacerbate the effects of the other, resulting in magnified harmful consequences. High-elevation, historically fishless lakes in the western United States, in particular, have been harmed by the introduction of non-native fishes, often resulting in competition with resident amphibians and potentially causing changes in amphibian foraging. New research suggests that

amphibians may be more sensitive to mercury effects than previously thought. Thus, changes in amphibian foraging induced by non-native fishes may result in altered mercury risk. USGS ecologist Collin Eagles-Smith is evaluating amphibian mercury exposure in Olympic National Park, WA and assessing the influence of fish presence on mercury cycling, bioaccumulation, and food webs in the Park's mountain lakes. Results will assist resource managers to address mercury issues in Olympic National Park and publicly managed lands with similar resources. **Contact**: Collin Eagles-Smith, FRESC, 541-750-0949, ceagles-smith@usgs.gov

Evaluating risks of non-lead environmental contaminants to California condors

The endangered California condor faces numerous threats to its recovery. In particular, exposure to environmental contaminants contributed to the condor's decline and still affects reproduction and adult survival. Because condors feed exclusively on carrion, lead exposure is problematic and well-documented. A provisioning program provides condor's access to lead-free food, but because condors are wide-ranging, they often feed on beached marine mammals, which can carry high levels of other extremely toxic environmental contaminants, such as mercury, PCBs, and flame retardants. Little is known about the relative importance of these alternative foods or their relationship with exposure to other contaminants. A new USGS study in partnership with the National Park Service assesses condor exposure to non-lead contaminants, investigates contaminant sources, and evaluates the energetic and nutritional value of proffered foods. Results will provide collaborators with new information about the health of condors and their contaminant risks at new potential release sites. **Contact**: Collin Eagles-Smith, FRESC, 541-750-0949, ceagles-smith@usgs.gov

Mercury cycling and ecological risk in Mount Rainier National Park lakes

Many national parks are in pristine or isolated areas, but they are not immune to the effects of mercury pollution. Mercury is a major conservation issue for all national parks because it is transported by the atmosphere for long distances; once deposited, the aquatic cycling is controlled by local processes; and a small amount of mercury can be converted to highly toxic methylmercury. Recent research determined that all fish sampled from small lakes in Mount Rainier National Park (MORA), WA, exceeded health standards for fish-eating animals, and some fish exceeded human-health thresholds. USGS ecologist Collin Eagles-Smith will lead a new study that uses higher resolution methods to focus on the magnitude and extent of contamination in MORA lakes. Further, researchers will determine ecological and human risk, evaluate how mercury risk varies across areas and habitat types, and develop a predictive model of mercury risk for MORA aquatic habitats. **Contact**: Collin Eagles-Smith, FRESC, 541-750-0949, ceagles-smith@usgs.gov

Mercury cycling, bioaccumulation, and risk in Western North America

Although mercury contamination is a serious environmental problem, local and regional processes are largely responsible for producing the highly toxic form methylmercury. In western North America, the combination of diverse landscapes, habitat types, climates, and mercury sources may disproportionally affect the region relative to other areas. Currently, there is no synthesis of mercury patterns in physical or biological resources across the region or simultaneous analysis of the factors that drive mercury risk. USGS ecologist Collin Eagles-Smith is leading an international team of scientists and policy experts to conduct a synthesis of mercury cycling and bioaccumulation throughout western North America in order to quantify the influence of land use, habitat, and climate factors on mercury risk. With public land comprising more than 60% of the total surface area in the region, this information is critical for effective management of resources to reduce mercury effects. See also: http://www.briloon.org/mercuryconnections/western **Contact**: Collin Eagles-Smith, FRESC, 541-750-0949, ceagles-smith@usgs.gov

Investigating mercury distribution and risk to wildlife in the Aleutians

Mercury is a globally distributed contaminant found even in remote and pristine environments. In those areas, mercury biomagnifies through food webs, reaching potentially toxic concentrations in wildlife. The Aleutian archipelago of Alaska is an isolated region that is critical for avian conservation, supporting more than 10 million nesting seabirds. Elevated mercury concentrations have been found in the tissues of Aleutian bird species, possibly because the archipelago lies along a direct corridor for Eurasian air masses, which may be important sources of mercury deposition. USGS scientist Collin Eagles-Smith and

cooperators are investigating the mercury risk to wildlife in the Aleutian archipelago by assessing mercury in sentinel fish species and seabird tissues. Further, they will link mercury distribution with projected climate change models in order to better understand how mercury risk might shift in the future. Results will facilitate U.S. Fish and Wildlife Service and Environmental Protection Agency managers to identify areas of conservation concern and mercury risk. **Contact**: Collin Eagles-Smith, FRESC, 541-750-0949, ceagles-smith@usgs.gov

Contaminant exposure, bioaccumulation, and ecological effects in aquatic and terrestrial habitats

The western region of the United States contains a diverse suite of aquatic habitats that provide critical ecosystem services. Environmental contaminants are among the key threats to the viability of these habitats and the species they support. Although the proximity of these water bodies to contaminant sources is important, the intrinsic ecological properties of each habitat type can affect contaminant cycling and effects. The USGS FRESC Contaminant Ecology Program is working across a range of aquatic habitats to evaluate contaminant exposure, assess the accumulation through the food web, and quantify the biological effects in aquatic and aquatic-dependent wildlife. Further, the habitat, landscape, and land-use patterns that contribute to contaminant dynamics will be measured. Focus areas include the Willamette and Columbia River systems, the Great Basin, the Klamath Basin, and large lakes throughout California. Targeted contaminants include mercury, selenium, PCBs and other organochlorines, flame retardants (PBDEs), and agricultural herbicides and insecticides. **Contact**: Collin Eagles-Smith, FRESC, 541-750-0949, ceagles-smith@usgs.gov

Evaluating wetland management practices to minimize methylmercury production and bioaccumulation in California's Central Valley

Mercury contamination is a priority issue nationwide, particularly in areas with extensive wetland networks. The unique biogeochemical properties of wetlands facilitate the conversion of inorganic mercury to methylmercury, which is more toxic to humans and wildlife. Widespread efforts to improve and restore wetlands, which are critical rearing and migration habitat for birds and fish, have the unintended potential of enhancing methylmercury production. USGS, Bureau of Land Management, and Moss Landing Marine Lab scientists are cooperating in a new study to evaluate management methods for minimizing methylmercury risk while maintaining healthy wetland function. Modifications of land use practices will be implemented across several dominant wetland types in the Central Valley of California, including rice fields, seasonal wetlands, and permanent wetlands, to reduce methylmercury discharge to the Sacramento-San Joaquin delta. Additionally, water management will be altered to control organic matter and timing and duration of inundation in seasonal wetlands. **Contact**: Collin Eagles-Smith, FRESC, 541-750-0949, ceagles-smith@usgs.gov

Mercury contamination in waterbird eggs and risk to avian reproduction at Bear River Migratory Bird Refuge and Great Salt Lake

The saline waters, freshwater wetlands, and mudflats of Utah’s Great Salt Lake are critical habitats for migratory and breeding shorebirds. Little is known about how environmental contaminants affect birds in the Great Salt Lake, but mercury concentrations in several species increased dramatically after they arrived at the lake. The Bear River Migratory Bird Refuge, the largest freshwater portion of the lake, provides foraging habitat for nearly a million migratory and breeding waterbirds. No systematic investigation has been conducted of mercury contamination in waterbirds or its effects on their reproduction. To determine how mercury accumulates in the ecosystem, USGS scientists will examine the eggs of several waterbird species of that have distinct diets, including aquatic insects, crustaceans, and fish. Results will provide refuge staff with important management information about which wetland areas are exposing birds to the highest levels of mercury accumulation. **Contact**: Collin Eagles-Smith, FRESC, 541-750-0949, ceagles-smith@usgs.gov

Effects of wetland restoration on mercury bioaccumulation in the South Bay Salt Pond Restoration Project: Using the biosentinel toolbox to monitor changes across multiple habitats and spatial scales

Two of the most significant human-caused changes in the San Francisco Bay estuary are loss of over 85% of tidal wetlands and mercury contamination from past mining. Recently, the largest wetland restoration project on the west coast of North America was initiated in San Francisco Bay to mitigate for previously lost wetlands. However, there is concern that these activities may remobilize additional mercury in the

system as tidal activity is restored to former salt ponds. Recent USGS studies have shown that mercury accumulation in some waterbird species in San Francisco Bay already exceeds toxicological thresholds and may be impairing egg and chick survival. USGS scientists are working on an integrative study to evaluate how the restoration will influence changes in mercury cycling and bioaccumulation in fish and birds, and ultimately risk to waterbird reproduction. Results will provide information for managers to minimize mercury risk while moving forward with restoration. **Contact**: Collin Eagles-Smith, FRESC, 541-750-0949, ceagles-smith@usgs.gov

Effects of herbicide applications for shrubland habitat restoration on ground-dwelling and pollinator insect communities on the Morley Nelson Snake River Birds of Prey National Conservation Area

The Morley Nelson Snake River Birds of Prey National Conservation Area (NCA) in southwestern Idaho provides critical habitat for wildlife and plants. The NCA management plan has identified the need for information about large-scale changes in habitat health caused by declining native shrubs, increasing invasive plants, and increasing fire frequency. USGS scientists are evaluating how herbicide treatments for invasive grasses affect insect communities. Insects are useful indicators for detecting changes because they are diverse, abundant, sensitive to weather changes, quick to respond to disturbances, and relatively easy to sample. Further, they are important pollinators and predators of plants and provide a critical food resource for wildlife species. Results of the study will assist managers to make decisions about treatment of invasive grasses as part of shrubland restoration activities. **Contact**: David Pilliod, FRESC, 208-426-5202, dpilliod@usgs.gov

Monitoring stream biota and habitats after Meadow Creek stream restoration in the Stibnite Mine tailings area and effects of prescribed fire in the Bald Hill Fuels treatment project area

Since the closure of the Stibnite gold mine in Idaho, the U.S. Forest Service, State of Idaho, and the Environmental Protection Agency have cooperated to restore the site. The major contaminant in the watershed is arsenic, with ground water containing some of the highest residues in the nation. The first restoration project on Meadow Creek was completed in 1998. The second project was completed in 2005 immediately downstream of the first project. The USGS will sample four portions of Meadow Creek for macroinvertebrates, including aquatic insects and mollusks, and measure habitat parameters, including stream temperature, gradient, and sediment levels, as indicators of restoration success. Results will be compared to data collected prior to stream restoration by the Payette National Forest scientists. **Contact**: David Pilliod, FRESC, 208-426-5202, dpilliod@usgs.gov

Emerging contaminants, endocrine disruption and reproductive & immunological health of fishes and amphibians

Researchers at the Leetown Science Center, Fish Health Branch have documented numerous examples of reproductive endocrine disruption in fishes. A high prevalence of feminization of bass (testicular oocytes, plasma vitellogenin in males) and white sucker (male plasma vitellogenin) in the Potomac and Susquehanna rivers, numerous tributaries of the Great Lakes and on or around Wildlife Refuges throughout the Northeast, have been documented. In the Potomac and Susquehanna watersheds, intersex in bass is correlated with agricultural land use, animal hormones and herbicide concentrations, while white sucker feminization appears to be more related to wastewater effluent. Reduced reproductive success of yellow perch has been noted in urbanized tributaries of the Chesapeake. In these fish, effects on egg quality (abnormal yolk, thin/abnormal chorion) in females and Leydig cell proliferation in males were observed. Testicular tumors have been observed in white sucker in selected tributaries of Lake Michigan. Current research is directed toward identifying sources, transport and effects of endocrine disruptors and other contaminants that may affect the reproductive health of fishes. In additional morphological, functional, physiological and molecular gene expression biomarker are being developed and applied to verify biological effects.

Blazer, V.S., L.R. Iwanowicz, H. Henderson, P.M. Mazik, J.A. Jenkins, D.A. Alvarez and J.A.Young. 2012. Reproductive endocrine disruption in Smallmouth Bass (Micropterus dolomieu) in the Potomac River Basin: Spatial and temporal comparisons of biological effects. Environ. Monitor. Assess. 184: 4309-4334.

Blazer, V.S., A. E. Pinkney, J. A. Jenkins, L. R. Iwanowicz, S. D. Zaugg, S. Minkkinen and J. H. Uphoff. 2013. Reproductive health of Yellow Perch Perca flavescens in selected tributaries of the Chesapeake Bay. Sci. Total Environ. 447:198-209.

Blazer, V.S., D.D. Iwanowicz, H.L. Walsh, A.J. Sperry, L.R. Iwanowicz, D.A. Alvarez, R.A. Brightbill, G. Smith, W.T. Foreman and R. Manning. In review. Reproductive Health of Fishes in Pennsylvania Watersheds: Association with Chemicals of Emerging Concern. Environ. Monitor. Assess.

Iwanowicz, LR, VS Blazer, NP Hitt, SD McCormick, DS DuVault, and CA Ottinger (2012) Histologic, Immunologic and Endocrine Biomarkers Indicate Contaminant Effects in Fishes of the Ashtabula River. Ecotoxicology. 21: 654-682

Kolpin, D.W., V.S. Blazer, J.L. Gray, M.J. Focazio, J.A. Young, D.A. Alvarez, L.R. Iwanowicz, W.T. Foreman, E.T. Furlong, G.K. Speiran, S.D. Zaugg, L.E. Hubbard, M.T. Meyer, M.W. Sandstrom and L.B. Barber. 2013. Chemical contaminants in water and sediment near fish nesting sites in the Potomac River Basin: Determining potential exposures to Smallmouth Bass (Micropterus dolomieu). Sci. Total Environ. 443:700-716.

Finding the sources of aquatic animal endocrine disrupting compounds in surface waters

Many surface and ground waters are contaminated with human and/or animal feces episodically or chronically via dysfunctional waste water treatment facilities, surface water run-off during storms and hurricanes, or poor management of agricultural animal operations. The components and risk factors associated with fecal contamination are multifaceted. Most obviously, human and animal diseases are spread in this way. Less obvious, perhaps, are the impacts of veterinary and human pharmaceuticals, and nutrient loads that are injected into the environment via fecal contamination. The National Fish Health Research Laboratory (NFHRL) has ongoing studies to identify the sources of aquatic animal endocrine disrupting compounds in surface waters. Studies using mitochondrial DNA (mtDNA) markers to identify fecal source were pioneered by laboratory staff and are now widely used.

Stelzer, E.A., Strickler, K.M., and Schill, W.B., 2012, Interlaboratory Comparison of Results for Three Microbial Source Tracking Quantitative Polymerase Chain Reaction (qPCR) Assays from Fecal-Source and Environmental Samples: Department of the Interior- U.S. Geological Survey.

Nutrient enrichment and freshwater ecosystems

Nutrient enrichment is a widespread environmental problem in freshwater ecosystems. Eutrophic conditions caused by nutrient enrichment may result in a higher prevalence of infection by trematode parasites in host populations, due to greater resource availability for the molluscan first intermediate hosts. This study examined relationships among land use, environmental variables indicating eutrophication, population density of the pleurocerid snail, Leptoxis carinata, and trematode infections.

Ciparis, S., D. D. Iwanowicz and J. R. Voshell. 2013. Relationships between nutrient enrichment, pleurocerid snail densities, and trematode infection rates in streams. Fish Biology 58 (7): 1392-1404.

Other Recent Publications of Interest

Abbey-Lambertz, M., A. Ray, M. Layhee, C. Densmore, A. Sepulveda, J. Gross, B. Watten. (2013). Suppressing Bullfrog Larvae with Carbon Dioxide. Journal of Herpetology. In Press

Iwanowicz, D.D., L.R. Iwanowicz, N.P. Hitt, and T.L.King. 2013. Differential Expression Profiles of microRNA in the Little Brown Bat (*Myotis lucifugus*) Associated with White Nose Syndrome Affected and Unaffected Individuals. Open file report: http://pubs.usgs.gov/of/2013/1099/

Cross, PC, TG Creech, MR Ebinger, E Maichak, J Henningsen, K Irvine, K Manlove, J Rogerson, B Scurlock, S Creel. *Online.* Elk contact rates are neither density nor frequency dependent. *Ecology.*

USGS researchers, in collaboration with Wyoming Game and Fish Department and Montana State University used proximity logger technology to assess the relationship contact rate and elk group size, which is a critical component of disease transmission. The new devices record contacts at a fine spatial and temporal scale within 2 meters, and the statistical approaches developed allow the researchers to assess the mechanisms that create superspreading events. Understanding these processes is critical to the development of effective disease control measures at a population scale.

Joseph, MB, JR Mihaljevic, AL Arellano, JG Kueneman, DL Preston, PC Cross, PTJ Johnson. 2013. Taming wildlife disease: closing the loop between science and management. *Journal of Applied Ecology*. 50:702-712.

Researchers at the University of Colorado, Boulder and the US Geological Survey reviewed the literature on how disease ecology theory is being incorporated into the management of wildlife diseases. Some theoretical concepts, such as density-dependent transmission, are commonly used to inform control measures while others, such as within-host parasite interactions have not been integrated into management actions.

Cassirer, EF, RK Plowright, K Manlove, KA Potter, PC Cross & PJ Hudson. *2013.* Spatio-temporal dynamics of pneumonia in bighorn sheep (*Ovis canadensis*). *Journal of Animal Ecology*. 82:518-528.

A consortium of researchers published a summary of the bighorn sheep pneumonia outbreaks over the last 14 years in the Hells Canyon region of Idaho, Oregon, and Washington. Initial outbreaks caused extensive mortality of adults and lambs, and this was often followed by years of poor lamb recruitment. Due to the high adult survival rates after the initial invasion events the full effects of disease may not be fully realized until senescent adults die and are not replaced by recruitment.