# Invasive Species Early Detection and Rapid Response: Resource Guide

**Prepared by the U.S. Department of the Interior and National Invasive Species Council Secretariat 2/17/2016 as a companion document to the report, *Safeguarding America's Lands and Waters from Invasive Species: A National Framework for Early Detection and Rapid Response***

> "Invasive species pose one of the most significant ecological threats to America's lands and waters. Early detection and rapid response actions can reduce the long-term costs, economic burden, and ecological harm that they have on communities. Strong partnerships and a shared commitment among Federal agencies, states, and tribes to preventing the spread of invasive species can lay the foundation for more effective and cost-efficient strategies to stop their spread."
>
> *U.S. Department of the Interior Principal Deputy Assistant Secretary Kristen J. Sarri.*

Invasive species—non-native species whose introduction causes or is likely to cause economic or environmental harm or harm to human and animal health—pose one of the greatest ecological threats to the Nation's natural resources. The stakes are high: if left to spread, invasive species cost billions of dollars to manage and can have devastating consequences on the Nation's ecosystems, economy, and human health.

Hundreds of invasive species are already established in the U.S., including brown rats, house mice, emerald ash borer, Asian carp, cheatgrass, kudzu, Asian tiger mosquitos, and the microscopic chytrid fungus that has devastated amphibian populations. Of substantial concern are the potentially harmful organisms that have not yet established in the U.S. but are threatening to do so. Examples include the spotted lanternfly and Zika virus.

If potentially harmful non-native organisms are detected and eradicated before they can become established in the U.S., the Federal Government will not only safeguard the environment and human well-being from invasive species impacts, but also potentially save billions of dollars that would otherwise have to be spent to repair damage and enact measures to control invasive species, costs that may go on indefinitely.

In the context of biological invasion, early detection and rapid response (EDRR) is a series of sustained and coordinated actions to eradicate an invasive species population before it establishes and spreads so widely that eradication (i.e. the elimination of the population) is no longer feasible. More specifically, early detection is a process for surveying for, reporting, and verifying the presence of a non-native species before the founding population becomes established or spreads. Rapid response is a process to eradicate the founding population of a non-native species from a specific location.

Invasive species infestations often cross jurisdictional boundaries; thus, coordination among neighboring jurisdictions is essential for EDRR to be successful. While partnerships need to be context-specific, they often include Federal, state, tribal, and local governments, as well as regional authorities and a range of site-based partners, including landowners, local naturalists, and issue experts.

The following information provides testimony from stakeholders and case studies that illustrate the importance of EDRR and working together to safeguard the Nation's lands and waters from invasive species.


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## STAKEHOLDER TESTIMONY

"More can be done to strengthen the Nation's EDRR capacity. We must get ahead of the next invasive species. A national EDRR Framework could build the capacity needed to forecast which species pose the greatest risks to the country, bolster current monitoring and response actions underway across the country, and position public and private partners to take immediate action when the next invasive species arrives, as assuredly, it will."

*Bob Wiltshire, Executive Director, Invasive Species Action Network, Livingston, MT, 406-222-7270, bob@stopans.org*

"An effective national EDRR program will require the leadership of government at all levels, industries, and private citizens. This is not someone else's problem. Invasive species have the potential to show up in anyone's backyard, with devastating consequences for commerce and the environment. This must become a top priority and stay a top priority."

*Eric Lane, Director of Conservation Services, Colorado Department of Agriculture, Lakewood, CO, 303-239-4182, eric.lane@ag.state.co.us*

"Western Governors support coordinated, prevention efforts of early detection and rapid response with multistate management and eradication actions to limit or eliminate introductions and improve control of invasive species expansion. Programs for the control and/or eradication of invasive species must result in more on-the-ground prevention, management and eradication."

*Western Governors' Association Policy Resolution 2013-02; Contact - Zach Bodane (WGA), Policy Advisor, Western Governors Association, Denver, CO, 720-897-4535, zbodhane@westgov.org*

"In addition to prevention, early detection and rapid response is the most cost-effective tool to limit invasive plant and animal species introductions from becoming established. With the ever expanding human population and the various modes and ease of travel, the conduit for invasive and non-native species introductions is virtually continuous. Being vigilant and responding effectively is and will continue to be a key technique in maintaining healthy native plant and animal communities."

*Christopher J. Fisher, Fisheries Biologist, Colville Confederated Tribes, WA, 509-422-2121, Chris.Fisher@ColvilleTribes.com*

"Early detection and rapid response is the key to safeguarding American ecosystems from the serious risks posed by invasive species, and the key to protecting federal, state, and local government agency budgets from the exorbitant costs of fighting invasive species that get out of control on the landscape."

*Scott J. Cameron, President, Reduce Risks from Invasive Species Coalition, Washington, DC, 703-909-2880, Scott.Cameron@rrisc.org*

"Early eradication of invasive plants at the landscape level is our top priority. By stopping new invasive plant infestations before they spread, we strengthen wildlife habitat and working lands. It's an immediate action we can—and should—take to support climate adaptation."

*Doug Johnson, Executive Director, California Invasive Plant Council, past-Chair, National Association of Invasive Plant Councils, Berkley, CA, 510-843-3902x302, dwjohnson@cal-ipc.org*

"The ecological and economic costs of invasive species far exceed the costs of preventing new invaders from establishing. A National Early Detection/Rapid Response Framework provides a coordinated approach by federal agencies that benefits states and local communities as we collaboratively grapple with prevention of new invaders."

*Judith Pederson, Research Affiliate, MIT Sea Grant College Program, Cambridge, MA, 617-253-9310, jpederso@mit.edu*

"New York is particularly vulnerable to invasive species due to its ports, canal system and extensive transportation network and has invested over $20,000,000 over the last decade to address invasive species. Federal partners such as the US Army Corps of Engineers, the US Fish and Wildlife Service, and the US Department of Agriculture have been indispensable in providing funding and expertise to assist in our efforts. Building on such collaborations, with a focus on early detection and rapid response, is essential to cost-effective approaches to helping states protect their natural and economic resources from invasive species."

*Kathy Moser, Assistant Commissioner, Office of Natural Resources, New York State Department of Environmental Conservation, Albany, NY, 518-402-8533, Kathleen.moser@dec.ny.gov*

"A national *EDRR Framework* is exactly what we need to help direct and support work at the state and local level. The lack of such direction has lead to a fractured approach that has facilitated the expansion of invasive species."

*Ken Mayer, Western Association of Fish and Wildlife Agencies Coordinator, Fire and Invasives Initiative, Western Association of Fish and Wildlife Agencies, Reno, NV, 775-741-0098, ken.e.mayer@gmail.com*

"An early detection and rapid response program for invasive aquatic plants in Iowa has allowed us to successfully eradicate new infestations of Eurasian watermilfoil at an ease and cost substantially less than managing ongoing infestations. This, along with public education, has limited the spread of Eurasian watermilfoil in Iowa. Our small program is an example of the ecosystem protection we could see at a large scale with a national program of early detection and rapid response."

*Kim Bogenschutz, Aquatic Invasive Species Program Coordinator, Iowa Department of Natural Resources, Des Moines, IA, 515-432-2823x103, Kim.Bogenschutz@dnr.iowa.gov*

"Invasive species threaten our ecosystems as well as our state and national economies. Early detection and rapid response makes the management of invasives more effective and efficient. This national EDRR framework will not only provide direction to our management efforts, it will also increase protection of our valuable natural resources."

*Raquel Crosier, Executive Coordinator, Washington Invasive Species Council, Olympia, WA, 360-902-3088, raquel.crosier@rco.wa.gov*

"Surveillance and early eradication of new outbreaks of invasive forest pests are much more cost-effective than trying to limit the spread of an established pest, or dealing with the ecological and economic damage in its aftermath. The nation needs a comprehensive and integrated framework for early detection and rapid response to minimize the risk of new pest invasions. "

*Gary M. Lovett, PhD, Senior Scientist, Cary Institute of Ecosystem Studies, Millbrook, NY, 845-677-7600x132, LovettG@caryinstitute.org*

"Lake Tahoe's success in preventing and controlling the spread of aquatic invasive species is a testament to the benefits of a collaborative, holistic approach that a national Early Detection and Response framework embodies. Having such a national framework would provide us with a ready-made tool to further enhance and build upon our ability to protect our precious natural resources and economy."

*Dennis Zabaglo, Aquatic Resources Program Manager, Tahoe Regional Planning Agency, Stateline, NV, 775-589-5255, dzabaglo@trpa.org*

"The Lake Champlain Basin Program developed an all taxa Lake Champlain Basin Aquatic Invasive Species Rapid Response Management Plan in 2009 and has worked through a number of rapid responses with our New York, Vermont, and Quebec partners. We have seen this early detection and rapid response process work, and having lead agencies identified, coordinated action and communication with federal, provincial, state and local partners, and resources are critical to be successful. This National Framework will be a useful guide for states and regions looking to develop rapid response plans."

*Meg Modley, Lake Champlain Basin Program Aquatic Invasive Species Management Coordinator, Grand Isle, VT, 802-372-3213x215, mmodley@lcbp.org*

"Early detection and rapid response is the key to minimizing the damage from invasive species. If a new invasive species can be found soon after its introduction, there is a chance of keeping it from becoming a major economic and environmental problem. If early detection and rapid response is not implemented, invasive species become expensive, long term management programs that only lessen their destructive impact."

*Jerry L. Cook, Ph.D., Professor of Biology, Executive Director of the Texas Invasive Species Institute, Associate Vice President for Research, Office of Research and Sponsored Programs, Sam Houston State University, Huntsville, TX, 936-294-3620, BIO_JLC@SHSU.EDU*

"The State of Hawai'i has identified invasive species as one of the greatest threats to the state's economy, natural environment, agriculture, and to the health and lifestyle of Hawaii's people. Partnering with federal agencies in the early detection and response to these pests has prevented the establishment of many potentially devastating invasive species such as the brown tree snake and coconut rhinoceros beetle. We are excited to see the development of a national EDRR framework to support and enhance these partnerships."

*Scott E. Enright, Chairperson, Hawaii Department of Agriculture, Honolulu, HI, 808-973-9550, Scott.E.Enright@hawaii.gov*

"EDRR is a critical process in preventing, limiting, and mitigating the spread and impacts of invasive species. Our Center supports this tenant, and works to promote the adoption of robust EDRR programs nation-wide. And, we are active in the development of tools like EDDMapS, that aid natural resource managers and Citizen Scientists in this important endeavor."

*David Moorhead, Professor and Co-Director, University of Georgia – Center for Invasive Species and Ecosystem Health, Tifton, GA, 229-386-3298, moorhead@uga.edu*

"Recognizing the challenge that invasive species present to our natural resources is paramount to good stewardship, and we must be fully prepared to address this challenge. The national early detection and rapid response framework provides valuable guidance and recognizes the need for planning and collaboration across jurisdictional boundaries to enable early detection and appropriate, timely responses to invasive species—of particular importance in a changing climate. Many of these principles have been demonstrated successfully during more than 5 years of collaboration to address Asian carp in the Midwest."

*Kevin S. Irons, Aquaculture and Aquatic Nuisance Species Program Manager, Illinois Department of Natural Resources, Springfield, IL, 217-557-0719, kevin.irons@illinois.gov*

"Early detection and rapid response is a key element in addressing non-native species issues. It ties in directly with prevention as the most cost effective way of dealing with a multi-billion dollar problem. Having an EDRR framework to help address key issues including responsibility, collaboration, action, and funding moves us away from knee jerk reactions and ineffectual response towards organized plans and efficient responses."

*Lad Akins, Director of Special Projects, Reef Environmental Education Foundation (REEF), Key Largo, FL, 305-852-0030, Lad@reef.org*

"State fish and wildlife agencies pour millions into invasive species control and management as part of maintaining and restoring habitat for the fish and wildlife they are charged with managing. While prevention is the least costly course of action, when that is not possible, early detection and rapid response is the most cost-effective option to address containment and management."

*Priya Nanjappa, Program Manager, Amphibians and Reptiles, and Invasive Species, Association of Fish and Wildlife Agencies, Washington, DC, 202-838-3463, pnanjappa@fishwildlife.org*

"Island ecosystems are the epicenter of biodiversity, but unfortunately also the epicenter of the extinction crisis, the majority of which are caused by invasive alien species (IASs). Eradicating invasive species from islands is a proven conservation tool to protect threatened, native species and set them on a path of recovery. Preventing IAS invasions is the single most cost-effective action to ensure long-term sustainability of island biodiversity and avoid costly eradications. The EDRR presents a critical framework for preventing, limiting, and mitigating the spread of IAS to islands around the globe."

*Gregg Howald, North America Regional Director, Island Conservation, Santa Cruz, CA, 831-359 4787, gregg.howald@islandconservation.org*

"Invasive species are not just a North American problem, they are a global issue. This Early Detection and Rapid Response Framework highlights the need for greater shared commitment and will provide a very helpful template for application internationally to help stop the spread, establishment and impacts of new invasive species."

*Phil Cowan, Science Team Leader Wildlife Ecology and Management, Landcare Research, Lincoln, New Zealand, +64 3 321 9794, cowanp@landcareresearch.co.nz*

## Bsal (*Batrachochytrium salamandrivorans*) One to Watch For

*Bsal* is a microscopic fungal pathogen that can be lethal to salamanders by infecting them with the disease, chytridiomycosis. *Bsa*l was initially identified in Europe in 2013, after massive die-offs in fire salamanders (*Salamandra salamandra*) in the Netherlands. The pathogen has subsequently spread to other parts of Europe, including Belgium and Germany. In some locations, up to 96% of local fire salamander population has been killed. *Bsal* has not yet been detected in the US. Research suggests that control efforts taken after its introduction into an area would have marginal effectiveness. Targeted prevention and early detection measures are, therefore, critical to pre-empt its introduction and/or establishment in the US. The ecological costs of failure are significant; the southeastern US (particularly the Appalachian region) is the global hotspot for salamander diversity.

**Native range**: Asia where three salamander species (*Cynops cyanurus* – China, *Cynops pyrrhogaster* – Japan, and *Paramesotriton deloustali* – Vietnam) serve as 'reservoir hosts' for the pathogen.

**Ecosystem type**: *Bsal* is a microscopic fungal pathogen that is carried by salamanders. In addition to the three host species in its native range, *Bsal* can be carried by a number of other salamander species. Research is ongoing to identify those species susceptible to *Bsal*, as well as those that can serve as a vector for its transmission.

**Basic biology**: *Bsal* has aquatic zoospores that infect the skin of salamanders, resulting in skin lesions and ulcerations, which impair vital skin functions. This can lead to anorexia, ataxia and, frequently, death in susceptible species (usually within 2-3 weeks). The pathogen is likely transmitted through direct contact with an infected salamander or exposure to contaminated water or soil.

**Fun Facts**

- The US has the highest diversity of salamander species in the world, including 141 species in the known susceptible family, Plethodontidae (*Bsal* can also be lethal other species in the family Salamandridae).
- Over the past 6 years, the US has imported over 28 million amphibians, including a range of salamander species.
- In January 2016, the US Fish and Wildlife Service released an interim rule listing 201 species of salamander as potentially injurious wildlife under the Lacey Act. This decision is intended to prevent the importation of infected salamanders, thereby reducing the risk of *Bsal*'s introduction.
- *Bsal* is similar to its relative *Batrachochytrium dendrobatidis* (*B*d), which has caused the collapse of amphibian populations throughout the world, most especially frog populations in Australia, Central America and North America.

**Current and projected range**: Outside of its native range, *Bsal* is currently known to have invaded Belgium, Germany, and the Netherlands. Its projected range in the US is likely only limited by the range of native species susceptible to the pathogen.

**Pathway(s) of introduction:** The international trade in salamanders for pets, biological supply, and bait are potential pathways for the introduction of *Bsal*.

**Impacts**: In Europe, the spread of *Bsal* has resulted in the mortality of up to 96% of wild populations of fire salamanders. The susceptibility and rates of mortality of other salamander species is still under investigation.

**EDRR Action & Investment:** The US Fish and Wildlife Service has issued an interim rule under the Lacey Act banning the import of 201 species of salamanders that could serves as vectors for *Bsal*. The US

Geological Survey, in partnership with the Association of Fish and Wildlife Agencies, has helped organize a *Bsal* National Task Force with working groups focused on: response actions; surveillance and monitoring; research; diagnostics; decision support; data management; and, communication and outreach.

**Photos**:

Eft stage of a red-spotted newt, which could be impacted by Bsal (Walker County, GA)
(Credit: Alan Cressler, USGS)
http://www.usgs.gov/newsroom/article.asp?ID=4439#.VrjPzUorJpg

## *Caulerpa taxifolia* An Aquatic Success Story

An attractive species of macro alga (seaweed), *Caulerpa taxifolia* is commonly used as an ornamental decoration in marine aquariums. It may also be moved if it gets caught up in marine equipment (including boats, fishing gear, etc.) that is relocated. In 2000, a population of *C. taxifolia* was discovered near San Diego in Agua Hediondo and Seagate Lagoons, prompting one of the first marine rapid response efforts in the US. The introduced populations were officially declared eradicated in 2006. The eradication of *C. taxifolia* demonstrates the value of investing in the early detection of and rapid response to non-native species before they cause substantial harm.

**Native range**: Indian Ocean

**Ecosystem type**: Tropical marine coastal waters, although there is likely a strain that is cold-water tolerant.

**Basic biology**: *C. taxifolia* is a marine alga that grows along stalks with an array of leaf-like fronds. The seaweed can grow as fast as a centimeter a day, and severed parts are capable of further growth.

**Fun Facts**

- In 1984, *C. taxifolia* was introduced into the Mediterranean Sea most likely from the Oceanographic Museum of Monaco. As scientists and authorities debated the origin of the species and its potential effects, the seaweed expanded to cover thousands of acres.
- *C. taxifolia* is one of two alga listed in IUCN's 100 of the World's Worst Invasive Alien Species.
- *C. taxifolia* is listed as a Federal Noxious Weed by USDA.

**Current and projected range**: Currently, the only verified population of *C. taxifolia* in the US is in St. Tammany Parish, Louisiana. Its potential range could include the Gulf Coast, as well as southern portions of the East and West Coasts. Warming waters, as well as the introduction of a cold-water tolerant strain, could expand its northern limits.

**Pathway(s) of introduction:** *C. taxifolia* is commonly used as an ornamental in the aquarium trade, and its introduction has been associated with the dumping of small aquariums, or, in the case of Monaco, accidental discharges from a public aquarium. Ship anchors, fishing nets, and other marine equipment can spread *C. taxifolia* by transporting fragments of the alga to new areas.

**Impacts**: *C. taxifolia* produces dense mats with the potential to crowd out native aquatic plants, other algal species, and marine invertebrates. Its monocultural mats can also affect spawning habitats for fish and other marine organisms. Economic impacts can include a reduction in catch for commercial fishermen, as well as the costs of repairing fishing equipment, anchors, and boat propellers.

**EDRR Action & Investment:** In 2000, a population of *C. taxifolia* was discovered near San Diego in Agua Hediondo and Seagate Lagoons, prompting one of the first marine rapid response efforts in the US. The underwater infestation was covered with tarps filled with chlorine. Although the chlorine killed native aquatic plants and animals along with the population of *C. taxifolia*, the non-target effects were deemed acceptable in comparison to the potential impacts of the invasive algae.

The EDRR activities were undertaken by a number of governmental and non-governmental entities that ultimately organized themselves into the Southern California Caulerpa Action Team. Key players included the National Oceanic and Atmospheric Administration, the US Department of Agriculture, the California Department of Fish and Game, the San Diego Regional Water Quality Control Board, and the Santa Ana Regional Water Quality Control Board. The populations were officially declared eradicated in 2006. Total costs for the suite of early detection/rapid response activities associated with the removal of *C. taxifolia* are estimated at $7.7 million.

**Photos**:

*Caulerpa taxifolia*
(Credit: NOAA)
http://montereybay.noaa.gov/research/techreports/trmakowka2000.html

## Cheatgrass (*Bromus tectorum*) Protecting Critical Habitat

Cheatgrass is a well-known invasive grass that has already spread throughout much of the western US. It's known as an ecosystem transformer; it outcompetes native grasses, such as sage brush (genus *Artemisia*), and fuels intense fires where it has invaded rangeland areas. The alteration of habitat by cheatgrass is a primary threat to the greater sage-grouse (*Centrocercus urophasianus*), a species that has inspired tremendous conservation efforts by state and federal agencies. Although cheatgrass is present and abundant in much of the western rangeland, it may still be feasible to prevent cheatgrass from becoming dominant in the Great Basin and Eastern Range. The early detection of and rapid response to new infestations of cheatgrass are critical to protecting the 'good habitat' that remains for the greater sage-grouse and other sage-dependent species.

**Native range**: Mediterranean region of Africa, Asia, and Europe.

**Ecosystem type**: Cheatgrass is a grassland species often found primarily in zones receiving 150-560 mm of precipitation per year. It can survive in many types of soils, as well as disturbed areas.

**Basic biology**: Cheatgrass is an annual species of bunchgrass that germinates in the fall, overwinters as a seedling and then flowers in the spring or early summer. At maturity it can range from 40 to 90 cm in height, and a single plant can produce @300 seeds, which can remain viable for 2-5 years. The plant maintains an extensive, but shallow, root system that can reduce soil moisture, inhibiting the growth of other plants. In invaded habitats, cheatgrass often flowers earlier than native species and can respond quicker to the effects of wildfire faster than many native species. The plant's substantial biomass contributes significantly to the fuel load of invaded areas, exacerbating the risks and impacts of wildfire.

**Fun Facts**

- Aldo Leopold memorialized the impacts of cheatgrass in *A Sand County Almanac* (1949): "I listened carefully for clues whether the West has accepted cheat as a necessary evil, to be lived with until kingdom come, or whether it regards cheat as a challenge to rectify its past errors in land-use."

**Current and projected range**: Currently, cheatgrass is distributed throughout the US, with particular concentrations in the western grasslands. Uninvaded areas remain particularly in the Eastern Range (Colorado, Wyoming, Montana). Climate change may also shift the range of suitable habitat.

**Pathway(s) of introduction:** Cheatgrass was likely introduced into the U.S. in packing materials, ship ballast and as a contaminant of crop seed. Movement of seed by livestock, vehicles, and habitat disturbance may contribute to its spread.

**Impacts**: Cheatgrass and associated fires can transform habitat types containing sage brush, pinyon-juniper, mountain brush, and other shrub communities. Sage-dependent species, such as the greater sage grouse, are particularly vulnerable to the impacts of cheatgrass. Economically, cheatgrass is a major weed of winter wheat and winter rye and can reduce yields by up to one-third. While cheatgrass may serve as good forage early in the season, mature plants are highly unpalatable as their sharp-tipped seeds can cause sores in the mouths of grazing animals. Cheatgrass threatens the economic viability of western ranchers.

**EDRR Action & Investment:** In the development of conservation plans for the greater sage-grouse, state and federal agencies are identifying uninvaded grassland areas that may serve as suitable habitat for the bird. Deployment of early detection/rapid response systems to identify and respond to any introduction of cheatgrass or other invasive grasses is a critical component of efforts to ensure the future viability of those habitats for the greater sage-grouse.

**Photos**:

Cheatgrass stand
(Credit: L.J. Mehrhoff, University of Connecticut, Bugwood.org)
http://www.weedimages.org/browse/subthumb.cfm?sub=5214

Cheatgrass and fire
(Credit: Kari Greer, National Interagency Fire Center)
http://www.fws.gov/Refuges/refugeupdate/JulAug_2013/cheatgrass.html

Greater sage-grouse, an at risk species threatened by cheatgrass invasion
(Credit: National Park Service) http://www.nps.gov/crmo/learn/nature/greater-sage-grouse.htm

## Quagga and Zebra Mussels (*Dreissenids*) Protecting Western Waters

Non-native aquatic mussels, such as quagga and zebra mussels (*Dreissena rostriformis bugensis* and *Dreissena polymorpha*) have a long history of invasiveness in the US. Quagga and zebra mussels were first introduced into the Great Lakes region in the 1980s, and by the 1990s had spread through all of the lakes. Despite the extent of those invasions, there are still parts of the US particularly in western states that are working hard to keep their waterbodies and waterways free of invasive mussels.

**Native range**: Black and Caspian Seas.

**Ecosystem type**: Freshwater lakes and other waterways.

**Basic biology**: Quagga and zebra mussels are filter-feeding organisms and are closely related to each other. They are typically about 1 cm in length, but can grow up to 5 cm. The mussels can attach themselves to a range of submerged substrates, including populations of native clams (this tendency has led to the near extirpation of native unionid clams in Lake St. Clair and western Lake Erie). Adult mussels can produce up to a million eggs a year. Mature adults and their microscopic larvae, also called veligers, are a management concern, as both life stages are capable of producing invasive populations if moved to new waterbodies.

**Fun Facts**

- In 2007, Quagga mussels were discovered in Lake Mead, as well as Lakes Havasu and Mohave along the Colorado, making them the first sightings of invasive Dreissenid mussels west of the 100$^{th}$ Meridian. Populations have subsequently been identified in other waterbodies, including Lake Mead and Glen Canyon Dam.
- The Western Regional Panel of the Aquatic Nuisance Species Task Force (ANSTF) has been instrumental in bringing together state and federal agencies to cooperate and coordinate on a range of early detection/rapid response activities, including watercraft inspection and decontamination, training, research, and information exchange.
- In 2015, an *ad hoc* working group under the ANSTF and National Invasive Species Council (NISC) Secretariat produced a report outlining existing federal authorities to address the threat of aquatic invasive species, as well as a series of options to further strengthen efforts in this area.

**Current and projected range**: While Quagga and zebra mussels are concentrated in the Great Lakes region, they have subsequently spread to 29 states mostly in the eastern US. A few outlier populations have been discovered in southwestern states, which has prompted a redoubling of efforts by state and federal agencies to protect uninvaded areas of the West.

**Pathway(s) of introduction:** Quagga and zebra mussels were initially introduced to the Great Lakes through the exchange of ballast water of ships crossing the Atlantic. Subsequent to that initial introduction, quagga and zebra mussels have been spread through the movement of infested recreational boats to new water bodies.

**Impacts**: If invasive Dreissenids were to establish in the Columbia River Basin, projected infrastructural costs are estimated to include $2 million per hydroelectric facility to install treatment systems, with an additional annual maintenance costs of $100,000 per unit. Direct and indirect costs for Idaho alone are projected at over $94 million.

**EDRR Action & Investment:** There are a series of efforts and initiatives, such as the 100$^{th}$ Meridian Initiative and Building Consensus in the West, to halt the spread of invasive *Dreissenid* mussels to western water bodies. Many of those activities are being implemented in line with the Quagga-Zebra Mussel Action Plan for Western U.S. Waters (QZAP), initially adopted by the ANSTF in 2010 and re-

approved in 2015. Watercraft inspection and decontamination is a critical step for ensuring effective early detection/rapid response within the region.

Funding to fully implement the recommended actions of the QZAP total ~$47 million in up-front costs and additional annual expenditures of $60 million. These estimates include a range of prevention and early detection/rapid response activities, along with support to states for implementing their aquatic nuisance species management plans. To date, federal agencies have provided a range of technical and financial resources to support efforts to address the spread of invasive *Dreissenids* into western waters.

**Photos**:

Zebra mussel on right, Quagga mussel on left
(Credit: USGS NAS Database)
http://nas.er.usgs.gov/taxgroup/mollusks/zebramussel/zebra_gallery.aspx

Quagga mussels on boat propellor
(Credit: National Park Service)
http://www.nps.gov/glac/planyourvisit/ais.htm

## Spotted Lanternfly (*Lycorma delicatula*) EDRR in Action

This charismatic insect was discovered in Berks County, Pennsylvania in the fall of 2014, and subsequently has been found in neighboring counties. The spotted lanternfly feeds on more than 70 species of plant hosts, including grapes, apples, stone fruits, and pines. It can thereby be seen as a 'crossover species' that threatens both agricultural and natural areas. Since its distribution in the US is currently quite limited, the spotted lanternfly could become a 'poster child' for the early detection of and rapid response to invasive species. There is still an opportunity to eradicate it from the US.

**Native range**: China, India, Vietnam

**Ecosystem type**: The spotted lanternfly is native to parts of southern China and subtropical regions of southeast Asia. It can be found in a wide range of habitats that contain plant species that support its varying life stages of development (see below).

**Basic biology**: The spotted lanternfly is a planthopper that feeds on woody and non-woody plants by sucking that sap from the plant's phloem. Adults are ~1" in length with one set of spotted greyish wings and another set of red, black and white hind wings that are visible in flight. The female lays its egg masses on flat outdoor surfaces (~30-50 eggs per mass). In the US, nymphs hatch in late April to early May. The spotted lanternfly nymphs can feed on more than 70 species, including fruit, ornamental and woody trees.

**Fun Facts**

- In Chinese medicine the spotted lanternfly is used for providing relief from swelling.
- In their native range, the adult spotted lanternfly often prefers Tree of Heaven (*Ailanthus altissima*) as its host. Tree of Heaven is a widespread invasive tree found throughout the eastern US. Unfortunately, the spotted lanternfly doesn't limit itself to that host here.

**Current and projected range**: Currently, the spotted lanternfly is under quarantine in parts of four Pennsylvania counties (Berks, Bucks, Chester, and Montgomery). Experts believe that the species has been present since 2012. Research is ongoing regarding the insect's potential range; major constraints are likely to include limits on availability of host species and cold temperature extremes. However, the US population has already demonstrated that spotted lantern flies can tolerate temperatures colder than they are exposed to in Asia.

**Pathway(s) of introduction:** Research is still ongoing regarding the pathway(s) for the spotted lanternfly's introduction. It lays its egg masses outdoors on flat sources, which means that movement of a very wide range of natural and man-made objects (e.g., building materials, outdoor household and recreational items, garden and landscaping equipment, firewood, plants) from infested areas could serve as a pathway for its initial and further spread.

**Impacts**: The feeding habits of the spotted lanternfly can leave trees with 'wounds' that weep sap from their trunks. These wounds make the tree susceptible to fungal mats, stunted growth, and impacts by other organisms that feed on the sap. The insect poses a potential threat to a range of agricultural and forestry enterprises. Economic projections indicated that the spotted lanternfly could adversely impact the value of the following industries in Pennsylvania alone: grapes - $20.5 million, apples - $134 million, stone fruits - $24 million, and hardwoods - $12 billion.

**EDRR Action & Investment:** Four Pennsylvania counties are under a quarantine that forbids the movement of outdoor household articles, construction waste, firewood, yard waste, and other organic debris outside of the quarantine zone. Citizens are asked to be on the lookout for the insect and to scrape, bag, and destroy any egg masses. A multi-agency team of experts are investigating potential

eradication and control measures, detection methods, and outreach strategies. Trained surveillance teams are also actively determining the extent of the population.

In 2015, USDA provided $1.4 million to the Pennsylvania Department of Agriculture for research, control and surveillance, in addition to allocation of internal state and federal resources.

**Photos**:

Adult spotted lanternfly
(Credit: Holly Raguza, Pennsylvania Department of Agriculture, Bugwood.org)
http://www.insectimages.org/browse/detail.cfm?imgnum=5524069

Immature spotted lanternfly
(Credit: Lawrence Barringer, Pennsylvania Department of Agriculture, Bugwood.org)
http://www.insectimages.org/browse/detail.cfm?imgnum=5537180

## Zika Virus (genus *Flavivirus*) An Emerging Health Concern

The Zika virus is transmitted by mosquitoes and is a human health concern, particularly for infants. First identified in the late 1940s, Zika virus was generally limited to the equatorial belt. It has recently spread throughout the Americas. Since January 2016, a number of infected individuals have been identified in the US, although they were likely infected by mosquito bites during travels to regions with the virus. The common vector for transmitting the virus are mosquitoes in the *Aedes* genus (e.g., *A. aegypti*, *A. albopictus*), which also invasive in the US. Currently, there is no evidence that populations of invasive *Aedes* mosquitoes in the US are infected with the Zika virus, and the primary objective of early detection/rapid response actions is to ensure that the virus does not become established within the US.

**Native range**: The Zika virus was first isolated in Uganda in 1947, and was generally limited to the equatorial belts of Africa, Asia, and the Pacific.

**Basic biology**: As a virus, Zika needs a host. Vertebrate hosts were initially thought to be rhesus monkeys, although it is now clear that humans are also susceptible. Mosquitoes of the genus *Aedes* can serve as vectors for transmitting the virus to new hosts. The Zika virus is primarily transmitted through mosquito bites. Pregnant mothers can transmit it to the fetus. Other means of transmission include blood transfusions and sexual contact.

**Fun Facts**

- Zika virus gets its name from the Zika forest of Uganda, where it was first identified.
- Monkeys were the primary vertebrate host of Zika virus, until its rapid outbreak in human populations starting in 2007.
- Zika virus is related to dengue fever, yellow fever, and West Nile virus.
- The World Health Organization (WHO) has designated the virus as a Public Health Emergency of International Concern, meaning that cooperation among countries is critical for managing the outbreak.

**Current and projected range**: Initially limited to the equatorial belt, Zika virus has subsequently spread throughout Central and South America, Sub-Saharan Africa, as well as parts of southeast Asia and the Pacific. Its range is limited to that of its vectors (i.e., *Aedes* mosquitoes) and hosts (i.e., monkeys and humans). Currently, *Aedes* mosquitoes are generally limited to the southeastern US (*Aedes albopictus* has a slightly larger range). Warming surface temperatures associated with climate change are a particular concern as they may facilitate further expansion of *Aedes* mosquitoe populations.

**Pathway(s) of introduction:** The transport of mosquitoes vectoring the Zika virus is a critical concern. Pathways could include a number of different modes of transportation (e.g., air, rail, ship) and products, particularly those that might collect pools of standing water (e.g., the transport of used tires containing water has been associated with the spread of mosquitoes carrying West Nile virus). Humans traveling to infested regions can transport Zika if they are bitten by mosquitoes carrying the virus. They can then spread it to other people through pregnancy, blood transfusions and/or sexual contact.

**Impacts**: Reports from infected regions, particularly in Latin America, note that human health impacts can include increased risk of mycrocephaly in infants, Guillain-Barré syndrome (a neurological disorder) and symptoms including fever, rash, joint pain, and conjunctivitis.

**EDRR Action & Investment:** The Centers for Disease Control (CDC) within the Department of Health and Human Services (HHS) have initiated work on Zika virus. Initial efforts are focusing on surveillance, particularly the identification of infections in humans. The CDC has developed guidance to assist local authorities and other government agencies to monitor the public for individuals who may already have contracted the virus, as well as for mosquitoes carrying the virus. Infected individuals should take

precautions against mosquito bites as they could serve as reservoirs for introducing the Zika virus into new populations of *Aedes* mosquitoes. Longer term work on diagnostics, vector control, vaccines and therapeutics is also underway.

President Obama recently submitted an emergency request to Congress for $1.8 billion to support further control, research and educational activities on the Zika virus.

**Photos**:

Adult Asian tiger mosquito (Aedes albopictus) – vector of transmission
(Credit: Susan Ellis, Bugwood.org)
http://www.insectimages.org/browse/detail.cfm?imgnum=1366025