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Invasive Species Research—
Science for Prevention, Detection, Containment, and Control

Invasive species research within the U.S. Geological Survey's (USGS) Ecosystems Mission Area focuses on invasive plants, animals, and pathogens throughout the United States. USGS scientists provide science support to help solve the problems posed by these nonnative species while working with partners in the U.S. Department of the Interior (DOI), other Federal, State, and Territorial agencies, Tribes, industry, agriculture, and nonprofit organizations. Key components of USGS invasive species science include the development of novel prevention, prediction, early detection, containment, and control tools.

Invasive Species Facts

An invasive species is, with regard to a particular ecosystem, a nonnative organism whose introduction does or is likely to cause economic or environmental harm, or harm to human, animal, or plant health (U.S. Department of the Interior, 2021). An invasive species can be introduced from another continent (for example, cheatgrass, *Bromus tectorum*) or transported outside its native range within the United States (for example, American bullfrog, *Lithobates catesbeianus*).

- **Invasive species are everywhere and affect everyone**—Invasive species adversely affect every State, Territory, and Tribe in the Nation, from heavily populated urban centers to unpopulated wilderness areas.
- **People intentionally and unintentionally spread invasive species**—Increased global travel and trade provide pathways for both intentional and unintentional introductions of invasive species.
- **Invasive species are costly**—Every year, harm caused by invasive species costs governments, industries, and private citizens substantial economic losses into the billions of dollars (Crystal-Ornelas and others, 2021).
- **We all pay the cost of invasive species**—Farmers, ranchers, other private landowners, businesses, and all levels of government bear the costs to control the economic, health, and environmental threats posed by invasive species.
- **The impacts of invasive species are wide ranging**—Effects of invasive species include decreased agricultural production, competition with and predation on native plants and wildlife, impairment of critical water infrastructure, transmission of disease to wildlife and humans, threats to commercial and native fisheries, and reduced hunting, fishing, and other recreational opportunities such as boating and swimming (Nalepa and Schloesser, 2013; Mayfield and others, 2021).
- **Climate change affects invasive species, and invasive species affect the impacts of climate change**—Changing climate can exacerbate the impacts of some invasive species (including the spread of associated human and wildlife disease), alter existing ranges, open new introduction pathways, and decrease effectiveness of control tools. Likewise, invasive species can make ecosystems and communities less resilient to climate change (Hellmann and others, 2008; Hulme, 2017).

Focus Areas of Invasive Species Research

Invasive dreissenid mussels. Photograph by U.S. Geological Survey.

Invasive species research within the USGS focuses on a diverse array of DOI priorities including the following:

Prevention

- Preventing invasion of the Great Lakes and uninvaded waterways in the Mississippi River Basin by bighead (*Hypophthalmichthys nobilis*), black (*Mylopharyngodon piceus*) and silver (*H. molitrix*) carp; and
- Reducing the risk of invasive species introductions in the Hawaiian Islands and U.S.-affiliated Pacific Islands through shipping containers and other pathways.

Detection

- Providing nationwide reporting, monitoring, and tracking of all freshwater aquatic invasive species as part of a national early detection system;
- Building knowledge about population dynamics and detection methods for the Burmese python (*Python bivittatus*), black and white tegu (*Salvator merianae*), and other invasive reptiles in the Everglades and other parts of southern Florida;
- Assisting Federal, State, and Tribal partners by developing early detection methods for zebra (*Dreissena polymorpha*) and quagga (*D. bugensis*) mussels in the continental United States; and
- Predicting the spread of existing invasive plant populations in the continental United States through the INHABIT tool, which uses habitat suitability models to help public lands agencies target surveillance and other management activities.

Containment and Control

- Reducing existing populations of grass carp (*Ctenopharyngodon idella*) in the Great Lakes, and reducing populations of all four species of invasive carp in the Mississippi River Basin and named subbasins where they are already present;
- Control of sea lamprey (*Petromyzon marinus*) in the Great Lakes;
- Reducing impacts of the brown treesnake (*Boiga irregularis*) on Guam; and
- Predicting spread and supporting control efforts related to invasive plants such as cheatgrass, salt cedar (*Tamarix spp.*), Russian olive (*Elaeagnus angustifolia*), leafy spurge (*Euphorbia esula*), and buffelgrass (*Cenchrus ciliaris*).

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

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Genetics and Invasive Species Detection

Environmental deoxyribonucleic acid (eDNA) is a detection method that identifies the presence of target species in the environment by locating DNA fragments sloughed from scales, shed from skin cells, or excreted with fecal material that may include an animal's intestinal cells or cells from an organism the animal has eaten.

Using eDNA techniques to detect DNA from a target invasive species has recently emerged as a powerful tool for surveillance of invasive species in water, land, and even air. USGS scientists have refined methods to improve detection sensitivity, develop best practices, understand how eDNA changes over time, and decrease time between sampling and results.

USGS scientists have developed a portable eDNA detection kit for detecting bighead and silver carps and zebra and quagga mussels that provides results in less than an hour. This tool is being enhanced to include Asian fish tapeworm (*Schyzocotyle acheilognathi*), spiny water flea (*Bythotrephes longimanus*), and other species (Hofmeister and others, 2021; Kageyama and others, 2022).

The USGS also used eDNA sampling to detect invasive northern pike (*Esox lucius*) in several south-central Alaska lakes following eradication efforts, and to monitor the potential range expansion of Burmese pythons in southern Florida.

In Hawai'i, USGS scientists have collaborated with partners to develop, test, and validate an eDNA field method to detect the fungi that cause Rapid ʻŌhiʻa Death in mature ʻŌhiʻa lehua (*Metrosideros polymorpha*) trees (Atkinson and Roy, 2023).

In Hawai'i, USGS scientists have developed a successful eDNA field method to detect the fungus that causes Rapid ʻŌhiʻa Death (ROD) in mature ʻŌhiʻa trees in collaboration with partners. Photograph by Carter T. Atkinson, U.S. Geological Survey.

The USGS also is developing terrestrial eDNA protocols for invasive reptiles in areas susceptible to invasion and investigating the detection of airborne eDNA to identify invasive species in shipping containers.

USGS scientists are collaborating with other Federal partners to develop general standards for using eDNA in species detection, which will promote trust and rigor in this surveillance technology. These efforts also include creating an eDNA toolbox for managers and others to use to gain information about using eDNA methods in prevention and early detection activities, assistance in creating an eDNA communication plan with partners, a search tool to determine if eDNA tools are available for species and locations of interest, developing genetic tools to detect priority invasive species, and a genetic materials repository where DNA can be shared to make eDNA tool development more efficient (Mehta and others, 2007).

Early Detection and Rapid Response

While invasive species prevention is the first line of defense, even the best prevention efforts will not stop all invaders. When prevention fails, Early Detection and Rapid Response (EDRR) is an efficient and cost-effective part of invasive species management. It consists of a coordinated set of actions to find and eradicate potential invasive species in a specific location before they spread and cause harm.

USGS provides scientific support to DOI bureaus and other partners to aid in implementation of EDRR efforts and make informed management actions. In certain cases, USGS staff lead multiagency and partner rapid response efforts where their specific skill sets are required, such as regional leadership, EDRR research, and training.

As one example, USGS scientists are participating in a working group under the National Science and Technology Council effort to develop a national Marine and Great Lakes eDNA strategy (National Science and Technology Council, 2023). USGS scientists also are improving eDNA detection by publishing studies on priority species and enhancing the utility of eDNA results through the use of structured decision making. In addition, USGS is aiding the development of a surveillance network that includes use of large sets of traditional sampling and eDNA data to evaluate "hotspots" of invasive species introduction vulnerability.

USGS scientists are central in creating tools that will serve as the architecture of a national EDRR framework that will interconnect and coordinate various EDRR efforts and create an information management system to support EDRR decision making. Additionally, the USGS is engaged with partners in other EDRR work such as using eDNA as an early detection tool for dreissenid mussels in the western United States, and the USGS is developing methods for using eDNA in the Great Lakes to locate new spawning areas for grass carp.

Buffelgrass is a nonnative perennial grass that is rapidly spreading across National Park Service (NPS) and adjacent lands in the Sonoran Desert in Arizona and California and can carry fire quickly across the landscape. USGS is working with the NPS and others on Early Detection and Rapid Response (EDRR) tools to detect invasive buffelgrass such as sensors aboard Unmanned Aerial Systems and high-resolution satellite imagery. Photograph by the National Park Service.

Another example of the USGS engagement in EDRR involves scientists working with partners on surveillance methods for use in terrestrial habitats. These projects include buffelgrass, a nonnative perennial plant that is rapidly spreading across National Park Service and adjacent lands in the Sonoran Desert in Arizona and California. It can form large, continuous patches that carry fire quickly and broadly across the landscape. The USGS is working with the National Park Service and others on EDRR remote-sensing tools to detect invasive buffelgrass, such as sensors aboard unmanned aerial systems and high-resolution satellite imagery.

USGS Advanced Tools and Technology—Continued

Nonindigenous Aquatic Species Database

The USGS Nonindigenous Aquatic Species (NAS) database (https://nas.er.usgs.gov/) contains one of the Nation's best sources of data on nonindigenous aquatic plant and animal species in the United States. The initiative to create the NAS database began with the Aquatic Nuisance Species Task Force, which was created by the U.S. Congress in 1990 (Public Law 101–646) to provide timely information to natural resource managers on locations of nonindigenous species.

The NAS database has been and continues to be a clearinghouse of information for confirmed sightings of nonindigenous aquatic species throughout the Nation. Useful tools developed for the NAS database include automated email alerts for species of interest, the ability to create maps and time-series of maps, species profiles, risk assessments, and bibliographies of scientific publications. These tools are used by managers to support prevention and control efforts. Recently, USGS scientists developed tools to assist managers in predicting potential range expansions of invasive lionfish (*Pterois volitans*) following weather-related flooding such as hurricanes, and in producing maps indicating potential rapid response areas after a new location is invaded.

Additionally, in partnership with DOI and other agencies, the USGS has created a public interface for incorporating eDNA detection data into the NAS database. This enhancement to the NAS database provides a unified source for integrated organismal and genetic observations of introduced aquatic species and allows for incorporation of eDNA into early detection and rapid response tools.

USGS scientists developed tools to assist managers in predicting potential range expansions of invasive lionfish (*Pterois volitans*) following weather-related flooding such as hurricanes, and in producing maps indicating potential rapid response areas after a new location is invaded. Photograph by Karen Doody, U.S. Geological Survey.

USGS Research Examples

Invasive Carp

High-density populations of bighead carp, black carp, grass carp, and silver carp, sometimes referred to collectively as invasive carp, have caused a range of negative impacts to the Nation's waterways. To provide management tools and technologies, the USGS conducts risk assessments, uses structured decision making, and researches ways to develop deterrents, pesticides, and removal methods, and to identify spawning areas. Management agencies use these tools to keep bighead, black, and silver carp out of the Great Lakes; to reduce grass carp where they occur in the Great Lakes; and to support management efforts in the six subbasins of the Mississippi River Basin to prevent invasions or reduce populations. Current field testing is being conducted by the USGS on underwater acoustic deterrents, bubble screens, baits and attractants, pesticides, and genetic methods to deter range expansion and reduce existing populations. The USGS has developed (1) the pesticide Carbon Dioxide Carp, (2) the Modified Unified Method of mass removal of silver and bighead carp, (3) the Fluvial Drift Simulator (FluEgg) to determine where grass carp spawn, and (4) SpawnCast, which assists field crews for planning sampling and removal efforts (Garcia and others, 2013; Cupp and others, 2021).

Grass Carp threaten nearshore and wetland vegetation that support native fish and reduce risk of shoreline erosion. USGS has developed methods to locate Grass Carp spawning locations where management agencies target removal efforts. Photograph by Patrick Kocovsky, U.S. Geological Survey.

USGS has extensive capabilities that have led to development of the risk assessment tool, Fluvial Egg Drift Simulator, for bighead, silver, and grass carp to predict where Asian carp are likely to spawn and where eggs and larvae will likely be located after spawning. Photograph by U.S. Geological Survey.

Sampling for Grass Carp eggs on the Sandusky River, a tributary of Lake Erie, to locate spawning areas, which are targeted for Grass Carp removal. Photograph by Nicole King, University of Toledo.

USGS Research Examples—Continued

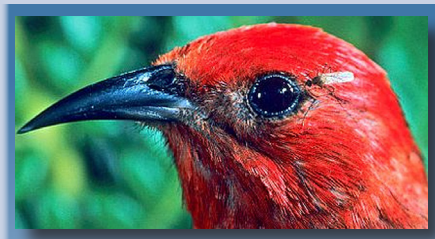
Burmese Pythons

Burmese pythons are large invasive snakes, which can exceed 18 feet and 150 pounds (Guzy and others, 2023). USGS scientists and partners documented that Burmese pythons have devastated the mammal communities in Everglades National Park and are known to have consumed threatened and endangered species including Wood Storks (*Mycteria americana*) and Key Largo woodrats (*Neotoma floridana smalli*) (Guzy and others, 2023). In addition to developing new tools for detection and control, USGS research on Burmese pythons is defining information on birth rates, movements, and other factors key to future management in Everglades National Park, Big Cypress National Preserve, and other DOI lands in southern Florida.

USGS scientists conduct research on invasive Burmese pythons in Everglades National Park and other DOI lands in South Florida to aid in the management of these large, voracious constrictor snakes. Photograph by U.S. Geological Survey.

Invasive Mosquitoes

In the Hawaiian Islands, warming climate has allowed the nonnative Southern house mosquito (*Culex quinquefasciatus*) to reach high-elevation forests, bringing deadly avian malaria and other pathogens to what had been the last remaining disease-free habitat for highly endangered native birds (Atkinson and LaPointe, 2009). In collaboration with many partners, the USGS is performing mosquito population assessment and other critical research to support use of the naturally occurring bacteria *Wolbachia* to act as mosquito "birth control" at a landscape scale.



The intersection of climate change, wildlife disease, and invasive mosquitos (such as the one shown near the eye of this 'apapane) threatens many species of Hawaiian forest birds with extinction. USGS is helping develop new tools to reduce mosquito impacts. Photograph by Jack Jeffrey, U.S. Fish and Wildlife Service.

Cheatgrass

Cheatgrass and other invasive grasses continue to expand into sagebrush ecosystems in the western United States. Cheatgrass colonizes burned areas before native plants can become established, providing more fuel and intensifying the cycle of fire and invasive plants. USGS scientists are assessing strategies to restore native vegetation to fight cheatgrass invasion and increase postfire resilience in a changing climate. These strategies include modeling postfire recovery times and developing fire management protocols that include potential alternatives to chemical and mechanical cheatgrass control methods. The USGS also develops periodic maps of the percentage of cheatgrass cover, which can help land managers plan fire operations and protective measures for crucial wildlife habitats (Dahal and others, 2022).

Cheatgrass and other invasive grasses burning in an Idaho wildfire. USGS science support for cheatgrass mapping, spread prediction, and control can help land managers plan fire operations and protective measures for critical wildlife habitats. Photograph by the National Interagency Fire Center.

Brown Treesnakes

The brown treesnake (BTS) was accidentally introduced to Guam in the late 1940s and has caused global or island-wide extinction of 9 of 13 native forest birds (Fritts, 1988). This invader frequently short circuits power lines, causing costly power outages and is a significant risk for further introductions regionally and nationally. The USGS has played an essential role in developing control techniques such as traps and barriers to manage this pest and leads the regional BTS Rapid Response Team to ensure effective early detection and rapid response to BTS sightings in new locations on the Pacific Islands.

A brown treesnake crawls on some frangipangi blossoms in Guam, where significant quarantine efforts are implemented to prevent the introduction and establishment of this invasive snake elsewhere. Photograph by Bjorn Lardner, U.S. Geological Survey.

European Green Crab

European green crabs (*Carcinus maenas*) are established along both the eastern and western coasts of the United States. They have recently expanded into Tribal waters of the Pacific Northwest, where they are threatening Tribal fisheries for native Dungeness crab (*Metacarcinus magister*). USGS researchers are developing eDNA techniques for tracking their spread and are investigating their early-life history for potential use in developing control methods.

European Green Crab (*Carcinus maenas*) is one of the most widespread invasive marine species on the planet. They are voracious predators of clams and oysters, outcompete native crabs, and can disrupt essential fish habitat (Ens and others, 2022). Photograph by Patrick DeHaan, U.S. Fish and Wildlife Service.

Zebra and Quagga Mussels

Invasive zebra and quagga mussels (collectively called "dreissenid mussels") cause significant ecological and economic impacts that continue to increase as they spread across North America. Dreissenid mussels affect industrial and municipal infrastructure, recreational water use, and they severely alter aquatic ecosystems. The USGS has been conducting dreissenid mussel control and rapid response research in the Great Lakes and Upper Mississippi River Basins for several years including developing genetic tools for detecting and evaluating the application of molluscicides and assessing their effects on nontarget species. The USGS is also working with partners to develop a control method that injects carbon dioxide under mats that can be laid over areas with dreissenid mussels. In support of the DOIs Safeguarding the West from Invasive Species initiative, which aims to strengthen Federal Government efforts to address invasive mussels across the western United States in coordination with States and Tribes, the USGS evaluated genetic markers for early detection of dreissenid mussels and is working to improve eDNA sampling and analysis protocols and plans in the Northern Rocky Mountains and Columbia River Basin.

Invasive zebra mussels are now part of many of our Nation's lakes and rivers, and USGS science and technical assistance is assisting in the control and prevention of further spread of these and other damaging mollusks. Photograph by John Byrnes, U.S. Geological Survey.

Dreissenid mussels harm native unionid mussels by growing on their shells preventing them from eating and breathing and reproducing. USGS develops control methods to reduce dreissenid mussel populations. Photograph by Kathryn Holcomb.

USGS is developing tools to detect, capture, and forecast the spread of invasive reptiles in Florida, including egg-loving Argentine black and white tegu lizards (*Salvator merianae*). Photograph by U.S. Geological Survey.

Salt Cedar (Tamarisk)

Salt cedar, commonly known as "tamarisk," affects riparian ecosystems in the western United States including impact to plant communities, water loss, erosion, wildlife use, and human recreational resources. In collaboration with multiple partners, USGS scientists are studying the effectiveness of biological control to reduce salt cedar populations, and subsequent changes in riparian vegetation.

In arid and semiarid regions of the western United States, invasive shrubs and trees such as salt cedar (*Tamarix ramosissima*), also called tamarisk, have replaced native vegetation over the past few decades. The ability of salt cedar to produce many flowers, and therefore seeds, helps it dominate riparian habitat. Photograph by Pamela Nagler, U.S. Geological Survey.

Black and White Tegu

Black and white tegus (hereinafter, referred to as "tegu[s]") are large omnivorous lizards native to South America and are common in international pet trade. Tegu populations have become established in at least four counties in Florida, likely resulting from escaped or released pets, and are moving north (Quinn and others, 2022). Tegus eat a variety of plants and animals but specialize in consuming eggs from bird and reptile nests (including American Alligators, *Alligator mississippiensis*). USGS scientists recently demonstrated that conditions suitable for tegu survival may exist across the southern one-third of the continental United States (Goetz and others, 2021). USGS research on tegus includes developing and testing methods for detection as well as assessing ecological risks under a changing climate.

Sea Lamprey

The parasitic sea lamprey invaded the Great Lakes in the mid-20th century, devastating valuable native fisheries and coastal economies (Treska and others, 2021). The USGS plays a central role in sea lamprey control research by working with the Great Lakes Fishery Commission, the U.S. Fish and Wildlife Service, other State, Federal, and Tribal agencies, and academic institutions to provide science on sea lamprey biology, ecology, and control technologies. The USGS developed a novel trap and electrical-guidance array that is capable of removing 75 percent of invasive sea lamprey from a stream with minimal impacts to nontarget species and stream flow (Johnson and others, 2016). In addition, USGS scientists registered with the U.S. Environmental Protection Agency the first vertebrate pheromone, which when applied, can increase sea lamprey trap catch by 35 percent (Fredricks and others, 2021).

Sea lampreys feed on the blood and fluids of native fish, causing population declines in commercial and recreational species that are essential to the Great Lakes' multibillion dollar per year fishery. Photograph by Andrea L. Miehls, U.S. Geological Survey.

References Cited

Atkinson, C.T., and Roy, K., 2023, Environmental monitoring for invasive fungal pathogens of ʻŌhiʻa (*Metrosideros polymorpha*) on the Island of Hawaiʻi: Biological Invasions, v. 25, p. 399–410, accessed February 2, 2024, at https://link.springer.com/article/10.1007/s10530-022-02922-3.

Atkinson, C.T., and LaPointe, D.A., 2009, Introduced avian diseases, climate change, and the future of Hawaiian honeycreepers: Journal of Avian Medicine and Surgery, v. 23, no. 1, p. 53–63, accessed February 2, 2024, at https://doi.org/10.1647/2008-059.1.

Crystal-Ornelas, R., Hudgins, E.J., Cuthbert, R.N., Haubrock, P.J., Fantle-Lepczyk, J., Angulo, E., Kramer, A.M., Ballesteros-Mejia, L., Leroy, B., Leung, B., López-López, E., Diagne, C., and Courchampet, F., 2021, Economic costs of biological invasions within North America: NeoBiota, v. 67, p. 485–510, accessed February 2, 2024, at https://doi.org/10.3897/neobiota.67.58038.

Cupp, A.R., Brey, M.K., Calfee, R.D., Chapman, D.C., Erickson, R., Fischer, J., Fritts, A.K., George, A.E., Jackson, P.R., Knights, B.C., Saari, G.N., and Kočovský, P.M., 2021, Emerging control strategies for integrated pest management of invasive carps: Journal of Vertebrate Biology, v. 70, no. 4, p. 1–21, accessed February 2, 2024, at https://doi.org/10.25225/jvb.21057.

Dahal, D., Pastick, N.J., Boyte, S.P., Parajuli, S., Oimoen, M.J., and Megard, L.J., 2022, Multi-species inference of exotic annual and native perennial grasses in rangelands of the western United States using harmonized landsat and sentinel-2 data: Remote Sensing, v. 14, no. 4, 21 p., accessed February 2, 2024, at https://doi.org/10.3390/rs14040807.

Ens, N.J., Harvey, B., Davies, M.M., Thomson, H.M., Meyers, K.J., Yakimishyn, J., Lee, L.C., McCord, M.E., and Gerwing, T.G., 2022, The Green Wave—Reviewing the environmental impacts of the invasive European green crab (*Carcinus maenas*) and potential management approaches: Environmental Reviews, v. 30, no. 2, p. 306–322, accessed February 9, 2024, at https://doi.org/10.1139/er-2021-0059.

Fredricks, K., Johnson, N., Hubert, T., and Siefkes, M., 2021, Registration and application of sea lamprey pheromones for sea lamprey control in the United States and Canada: Journal of Great Lakes Research, v. 47, supplement 1, p. S448–S454, accessed February 2, 2024, at https://doi.org/10.1016/j.jglr.2020.07.017.

Fritts, T.H., 1988, The brown tree snake, *Boiga irregularis*, a threat to Pacific islands: Washington, D.C., U.S. Fish and Wildlife Service, Biological Report 88–31, 36 p.

Garcia, T., Jackson, P.R., Murphy, E.A., Valocchi, A.J., and Garcia, M.H., 2013, Development of a fluvial egg drift simulator to evaluate the transport and dispersion of Asian carp eggs in rivers: Ecological Modelling, v. 263, p. 211–222, accessed February 2, 2024, at https://doi.org/10.1016/j.ecolmodel.2013.05.005.

Goetz, S.M., Steen, D.A., Miller, M.A., Guyer, C., Kottwitz, J., Roberts, J.F., Blankenship, E., Pearson, P.R., Warner, D.A., and Reed, R.N., 2021, Argentine black and white tegu (*Salvator merianae*) can survive the winter under semi-natural conditions well beyond their current invasive range: PLoS One, v. 16, no. 3, e0245877, accessed February 2, 2024, at https://doi.org/10.1371/journal.pone.0245877.

Guzy, J.C., Falk, B.G., Smith, B.J., Willson, J.D., Reed, R.N., Aumen, N.G., Avery, M.L., Bartoszek, I.A., Campbell, E., Cherkiss, M.S., Claunch, N.M., Currylow, A.F., Dean, T., Dixon, J., Engeman, R., Funck, S., Gibble, R., Hengstebeck, K.C., Humphrey, J.S., Hunter, M.E., Josimovich, J.M., Ketterlin, J., Kirkland, M., Mazzotti, F.J., McCleery, R., Miller, M.A., McCollister, M., Parker, M.R., Pittman, S.E., Rochford, M., Romagosa, C., Roybal, A., Snow, R.W., Spencer, M.M., Waddle, J.H., Yackel Adams, A.A., and Hart, K.M., 2023, Burmese pythons in Florida—A synthesis of biology, impacts, and management tools: NeoBiota, v. 80, p. 1–119, accessed February 2, 2024, at https://doi.org/10.3897/neobiota.80.90439.

Hellmann, J.J., Byers, J.E., Bierwagen, B.G., and Dukes, J.S., 2008, Five potential consequences of climate change for invasive species: Conservation Biology, v. 22, no. 3, p. 534–543, accessed February 2, 2024, at https://doi.org/10.1111/j.1523-1739.2008.00951.x.

Hofmeister, E., Georgousi, F., Lund, M., Roderick, C., Choudhury, A., Whelan, G., and Cole, R., 2021, Loop-mediated isothermal amplification (lamp) assay for detection of Asian fish tapeworm, *Schyzocotyle acheilognathi* (Yamaguti, 1934) [syn. *Bothriocephalus acheilognathi*]: Journal of Parasitology, v. 107, no. 6, p. 846–852, accessed February 2, 2024, at https://doi.org/10.1645/21-56.

Hulme, P.E., 2017, Climate change and biological invasions—Evidence, expectations, and response options: Biological Reviews, v. 92, no. 3, p. 1297–1313, accessed February 2, 2024, at https://doi.org/10.1111/brv.12282.

Johnson, N.S., Miehls, S., O'Connor, L.M., Bravener, G., Barber, J., Thompson, H., Tix, J.A., and Bruning, T., 2016, A portable trap with electric lead catches up to 75% of an invasive fish species: Nature Scientific Reports, v. 6, article no. 28430, p. 1–8, accessed February 2, 2024, at https://doi.org/10.1038/srep28430.

Kageyama, S.A., Hoogland, M.R., Tajjioui, T., Schreier, T.M., Erickson, R.A., and Merkes, C.M., 2022, Validation of a portable eDNA detection kit for invasive carps: Fishes, v. 7, no. 6, p. 1–18, accessed February 2, 2024, at https://doi.org/10.3390/fishes7060363.

Mayfield, A.E., Seybold, S.J., Haag, W.R., Johnson, M.T., Kerns, B.K., Kilgo, J.C., Larkin, D.J., Lucardi, R.D., Moltzan, B.D., Pearson, D.E., Rothlisberger, J.D., Schardt, J.D., Schwartz, M.K., and Young, M.K., 2021, Impacts of invasive species in terrestrial and aquatic systems in the United States, *in* Poland, T.M., Patel-Weynand, T., Finch, D.M., Miniat, C.F., Hayes, D.C., and Lopez, V.M., eds., Invasive species in forests and rangelands of the United States—A comprehensive science synthesis for the United States forest sector: Cham, Switzerland, Springer Nature, p. 5–39. [Also available at https://doi.org/10.1007/978-3-030-45367-1.]

Mehta, S.V., Haight, R.G., Homans, F.R., Polasky, S., and Venette, R.C., 2007, Optimal detection and control strategies for invasive species management: Ecological Economics, v. 61, nos. 2–3, p. 237–245, accessed February 2, 2024, at https://doi.org/10.1016/j.ecolecon.2006.10.024.

Nalepa, T.F., and Schloesser, D.W., 2013, Quagga and zebra mussels—Biology, impacts, and control [2d ed.]: Boca Raton, Fla., CRC Press, 815 p.

National Science and Technology Council, 2023, Request for information (RFI) N00014–23–RFI–0014—National Marine and Great Lakes eDNA strategy: National Science and Technology Council, 3 p., accessed February 2, 2024, at https://oceanexplorer.noaa.gov/technology/omics/media/docs/eDNA_N0001423RFI0014_RFI.pdf.

Quinn, D.P., Dallas, T.R., Cunningham, C.C., Hamilton, A.S., and Funck, S.A., 2022, An incipient population of Argentine black and white tegus (*Salvator merianae*) in Charlotte County, Florida, USA: Herpetological Conservation and Biology, v. 17, no. 3, p. 539–547, accessed February 2, 2024, at https://www.herpconbio.org/Volume_17/Issue_3/Quinn_etal_2022.pdf.

Treska, T.J., Ebener, M.P., Christie, G.C., Adams, J.V., and Siefkes, M.J., 2021, Setting and tracking suppression targets for sea lampreys in the Great Lakes: Journal of Great Lakes Research, v. 47, supplement 1, p. S357–S367, accessed February 2, 2024, at https://doi.org/10.1016/j.jglr.2021.10.007.

U.S. Department of the Interior, 2021, U.S. Department of the Interior Invasive Species Strategic Plan, fiscal years 2021–2025: Washington, D.C., U.S. Department of the Interior, 54 p., accessed February 2, 2024, at https://www.doi.gov/sites/doi.gov/files/doi-invasive-species-strategic-plan-2021-2025-508.pdf.

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