

RECLAMATION

Managing Water in the West

Ranking and Categorizing Aquatic Invasives of Concern

Research and Development Office
Science and Technology Program
Final Report ST-2019-7135-01



U.S. Department of the Interior
Bureau of Reclamation
Research and Development Office

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Mission Statements

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

The Department of the Interior (DOI) conserves and manages the Nation's natural resources and cultural heritage for the benefit and enjoyment of the American people, provides scientific and other information about natural resources and natural hazards to address societal challenges and create opportunities for the American people, and honors the Nation's trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities to help them prosper.

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Final Report ST-2019-7135-01

Ecological Research Laboratory

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Executive Summary

The Ecological Research Laboratory, formerly known as the Reclamation Detection Laboratory for Exotic Species / RDLES, investigates invasive, nuisance, and exotic species that might affect Reclamation assets, lands, and operations. The invasion and establishment of *Dreissena bugensis* (quagga) and *Dreissena polymorpha* (zebra) mussels in the western half of the country caught many experts by surprise. This was primarily due to the differences between their native climate and even the climate in which they thrive in the eastern US, and the arid climate of the western US. Unfortunately, they were introduced and successfully established in the warmer waters of southwest America. Due to their permanent settlement on hard surfaces including pipes, gates, racks, and underwater equipment, they immediately became problematic for Reclamation, costing money and manpower to address. Identifying other invasive organisms that might become problematic for Reclamation is an important subject to explore.

Other invasive organisms have also caused concern for Reclamation, including burrowing animals and vegetation that pulls excessive amounts of water from nearby water sources. Identifying additional potential threats to Reclamation regarding invasive, exotic, or nuisance species can help prevent the types of problems that the invasive mussels caused. An established reference list can help with early detection, identification, and management.

This research was primarily conducted by reaching out to Integrated Pest Management personnel in the five Reclamation Regions, and searching the internet for invasive organisms that are not yet in the western US or organisms that exist in the western US that might become an issue. Investigation was also conducted into which organisms have caused damage to international agencies with similar goals to Reclamation. Utilizing this research and resources like the National Invasive Species Council, US Geological Survey, and the Western Governor's Association, a list of organisms of concern was compiled.

There is no "one size fits all" for addressing invasive species. Likewise, there is no guarantee that even with early detection, full establishment can be avoided, or that if establishment of an invasive organism occurs, it will be problematic for Reclamation. Also, an organism that might be harmful in one location, might be completely benign in another. It is also worth noting that eradication methods are not applicable in all scenarios, as seen with attempts to address quagga and zebra mussels.

Next steps should include dissemination of this information to ensure that any Reclamation staff who might encounter any of these organisms are made aware of them and report them accordingly. This includes any staff who work in the field, at the area and operations offices, dams and hydropower facilities. The creation of a database or central location for information on these species would be beneficial.

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Background

Invasive species can be non-native plants, animals, and other organisms (e.g. microbes) whose introduction does or is likely to cause economic or environmental harm or harm to human health. They can be introduced to an area through natural pathways such as wind, water currents, and natural dispersal. They can also be introduced through man-made pathways, either intentionally or accidentally. Examples of man-made pathways include the introduction of biological control organisms, the horticultural and pet trades, ballast water discharge, imported agricultural products, and the movement of recreational watercraft. Today's global economy and various methods of transporting goods means that multiple avenues exist for the arrival of non-native species to the United States.

Due to the accelerated development of a "new habitat", manmade waterbodies and waterways such as reservoirs, canals, and irrigation channels are especially vulnerable to invasion by non-native organisms, making the threat of invasive and nuisance species a high priority to the Bureau of Reclamation.

Numerous aquatic and terrestrial invasive and nuisance species exist in the United States but have not yet traveled into the 17 western states where Reclamation facilities exist. The Great Lakes are now home to over 180 different established invasive species, imported through ballast water and cargo, that have severely damaged the ecosystem. Many of those species have invaded other parts of the United States, including the western states. Aquatic organisms are transferred from one body of water to another by watercraft, or they move through rivers, streams, and canals throughout watersheds. For example, two species of mussels, *Dreissena polymorpha* (zebra mussel) and *Dreissena rostriformis* "bugensis" (quagga mussel), have become established in freshwater lakes, reservoirs, and rivers in the United States. Invasive dreissenid mussels pose significant challenges for Reclamation and all agencies and industries that manage water. Invasive mussels are prolific breeders and settle on or within water facility infrastructure such as water intakes, gates, diversion screens, hydropower equipment, pumps, pipelines, and boats. Infested water and hydropower infrastructure can fail or choke off water transmissions. Invasive mussels negatively impact the natural ecology, which can be detrimental to native and endangered species, including native fisheries.

Maintaining and operating water supply and delivery facilities, water recreation, and other water dependent industries and economies in mussel infested water bodies is dramatically more expensive and complex. Public recreation is also severely impacted by mussel infestations, from shell fragments degrading swim beaches to increased requirements and costs for boaters to have their watercraft inspected and decontaminated. Mussels also have potential impacts on populations of game fish.

While not all invasive organisms are from outside the US, those that are have the potential to cause the greatest economic and environmental damage simply because they are unknown in US habitats and do not have immediate natural predators to keep populations in check. Successful invasive organisms can survive in variable environmental conditions and reproduce, grow, and disperse quickly.

Invasive organisms can potentially outcompete native organisms or alter the environment so it is no longer suitable for native organisms, thus decreasing biodiversity. Invasive quagga and zebra mussels have already caused significant and costly damage to reservoirs, dams, hydropower facilities, boats and other aquatic vessels, in addition to altering the ecosystems they establish in.

Reclamation staff, managers, and leadership should be aware of other invasive or nuisance organisms that might establish in or around Reclamation facilities and cause damage or hinder operations.

Research Methods

Research was done primarily by conducting online subject searches based off suggestions of nuisance, invasive or exotic species reported by Reclamation staff. Reclamation Region and Area Office input was requested via email to existing members of the Reclamation Mussel Task Force and Integrated Pest Management committees, who then solicited information from their co-workers who work in the field. Results were compiled into a master list, which notes specific species that have greater potential to be detrimental. Criteria for determining these organisms included parameters such as impacts to infrastructure, water delivery hindrances, recreational deterrents, and environmental degradation.

Results

The final list is not all-inclusive as new species arrive in the US every year; nor should it be considered absolute as many of the species listed may never be problematic for Reclamation. Many of the vertebrate species provided are predatory game fish, which could undoubtedly affect recreation, biodiversity, and ecology, but not necessarily affect Reclamation operations and water delivery. Semi-aquatic animals with burrowing behavior like *Myocastor coypus* (nutria) and varieties of crayfish can cause ground instability, which presents a risk for canals and levees. The mass migrations of *Eriocheir sinensis* (Chinese Mitten Crab) can clog waterways, screens, and racks in shallow water areas. Plants like *Eichornia crassipes* (water hyacinth) have caused significant damage to waterways in other countries and should be monitored with caution where they exist in the western US.

A presentation (Appendix 1) was provided during the February 22, 2019, Joint Mussels Task Force / Integrated Pest Management Coordinators Meeting in Denver. The presentation highlighted several species of concern, demonstrating the diverse potential impacts to the Reclamation mission. The bottom-line message of this presentation, however, was that the Ecological Research Laboratory serves as a hub for all organisms impacting Reclamation facilities and waterbodies. Potential threats may be identified and explored further but there is no definitive method for determining how a new organism will spread or what impacts it will have.

Table 1: Plants of Concern

Common Name	Scientific Name	Common Name	Scientific Name
African waterweed	<i>Lagarosiphon major</i>	Sacred bamboo	<i>Nandina domestica</i>
Air potato	<i>Dioscorea bulbifera</i>	Sahara mustard	<i>Brassica tournefortii</i>
Alligator weed	<i>Alternanthera philoxeroides</i>	Salt cedar/tamarisk	<i>Tamarix spp.</i>
Asian marshweed	<i>Limnophila sessiliflora</i>	Scotch thistle	<i>Onopordum acanthium</i>
Asiatic bittersweet	<i>Celastrus orbiculatus</i>	Spotted knapweed	<i>Centaurea stoebe</i>
Brazilian elodea	<i>Egeria densa</i>	St John's wort	<i>Hypericum perforatum</i>
Buffelgrass	<i>Pennisetum cillare</i>	Tree tobacco	<i>Nicotiana glauca</i>
Cheatgrass	<i>Bromus tectorum</i>	Tree-of-heaven	<i>Ailanthus altissima</i>
Curly leaf pondweed	<i>Potamogeton crispus</i>	Tropical soda apple	<i>Solanum viarum</i>
Didymo or "rock snot"	<i>Didymosphernia geminate</i>	Water hyacinth	<i>Eichornia crassipes</i>
Duck weed	<i>Lemnoideae</i>	Water lettuce	<i>Pistia stratiotes</i>
Eurasian watermilfoil	<i>Myriophyllum spicatum</i>	Water spinach	<i>Ipomoea aquatica</i>
European waterchestnut	<i>Trapa natans</i>	Whitetop	<i>Lepidium draba</i>
Floating primrose-willow	<i>Ludwigia peploides</i>	Witchweed	<i>Striga asiatica</i>
Flowering rush	<i>Butomus umbellatus</i>	Yellow floating heart	<i>Nymphoides peltata</i>
Fountain grass	<i>Cenchrus setaceus</i>	Yellow iris	<i>Iris pseudacorus</i>
Giant reed	<i>Arundo donax</i>	Yellow star thistle	<i>Centaurea solstitialis</i>
Giant salvinia	<i>Salvinia molesta</i>	Yellow toadflax	<i>Linaria vulgaris</i>
Hairy willowherb	<i>Epilobium hirsutum</i>		
Hydrilla	<i>Hydrilla verticillata</i>		
Japanese hops	<i>Humulus japonicus</i>		
Knapweed	<i>Centaurea spp.</i>		
Melaleuca/paperbark tree	<i>Melaleuca quinquenervia</i>		
Mile-a-minute weed	<i>Persicaria perfoliata</i>		
Miramar weed	<i>Hygrophila polysperma</i>		
Mosquito fern/fairy moss	<i>Azolla pinnata</i>		
Multiflora rose	<i>Rosa multiflora</i>		
Musk thistle	<i>Carduus nutans</i>		
Old world climbing fern	<i>Lygodium microphyllum</i>		
Parrotfeather	<i>Myriophyllum aquaticum</i>		
Pepperweed	<i>Lepidium latifolium</i>		
Pickernel weed	<i>Monochoria vaginalis</i>		
Princess tree	<i>Paulownia tomentosa</i>		
Purple loosestrife	<i>Lythrum salicaria</i>		
Quackgrass/couch grass	<i>Elymus repens</i>		
Reed canary grass	<i>Phalaris arundinacea</i>		
Russian knapweed	<i>Rhaponticum repens</i>		
Russian olive	<i>Elaeagnus angustifolia</i>		

Table 2: Invertebrate Organisms of Concern

Common Name	Scientific Name
Asian clam	<i>Corbicula fluminea</i>
Asian clubbed tunicate	<i>Styela clava</i>
Asian shore crab	<i>Hemigrapsus sanguineus</i>
Asian swamp eel	<i>Monopterus albus</i>
Channeled apple snail	<i>Pomacea canaliculata</i>
Chinese mitten crab	<i>Eriocheir sinensis</i>
Colonial hydroid	<i>Cordylophora caspia</i>
European green crab	<i>Carcinus maenas</i>
European valve snail	<i>Valvata piscinalis</i>
Fishhook waterflea	<i>Cercopagis pengoi</i>
Giant African land snail	<i>Achatina fulica</i>
Giant rams-horn snail	<i>Marisa cornuarietis</i>
Killer shrimp	<i>Dikergammarus villosus</i>
New Zealand mud snail	<i>Potamopyrgus antipodarum</i>
Northwestern crayfish	<i>Orconectes virilis</i>
Ponto-Caspian amphipod	<i>Echinogammarus ischnus</i>
Red imported fire ants	<i>Solenopsis invicta</i>
Red swamp crayfish	<i>Procambarus clarkii</i>
Rusty crayfish	<i>Orconectes rusticus</i>
Spiny waterflea	<i>Bythotrephes longimanus</i>
Tawny crazy ant	<i>Nylanderia fulva</i>
Veined rapa whelk	<i>Rapana venosa</i>

Table 3: Vertebrate Organisms of Concern

Common Name	Scientific Name	Common Name	Scientific Name
Alewife	<i>Alosa pseudoharengus</i>	Rudd	<i>Scardinius erythrophthalmus</i>
Asian carp	<i>Hypophthalmichthys harmandi</i>	Ruffe (Eurasian)	<i>Gymnocephalus cernuus</i>
Bighead carp	<i>Hypophthalmichthys nobilis</i>	Silver carp	<i>Hypophthalmichthys molitrix</i>
Bitterling	<i>Rhodeus sericeus</i>	Smallmouth bass	<i>Micropterus dolomieu</i>
Black bullhead	<i>Ameiurus melas</i>	Stickleback	<i>Apeltes, Culaea, Pungitius, Gasterosteus, and Spinachia spp.</i>
Black carp	<i>Mylopharyngodon piceus</i>	Striped bass	<i>Morone saxatilis</i>
Black crappie	<i>Poxomis nigromaculatus</i>	Threadfin shad	<i>Dorosoma petenense</i>
Bluegill sunfish	<i>Lepomis macrochirus</i>	Tilapia	<i>Tilapia sp.</i>
Bowfin	<i>Amia calva</i>	Walking catfish	<i>Clarias batrachus</i>
Brown trout	<i>Salmo trutta</i>	Walleye	<i>Stizostedion vitreum</i>
Bullfrog	<i>Lithobates catesbeianus</i>	Yellow bullhead	<i>Ameiurus natalis</i>
Burbot	<i>Lota lota</i>		
Butterfly peacock bass	<i>Cichla, Cichla ocellaris</i>		
Cane toad	<i>Rhinella marina</i>		
Chain pickerel	<i>Esox niger</i>		
Channel catfish	<i>Ictalurus punctatus</i>		
Clawed African frog	<i>Xenopus laevis</i>		
European/common carp	<i>Cyprinus carpio</i>		
Fathead minnow	<i>Pimephales promelas</i>		
Flathead catfish	<i>Pylodictis olivaris</i>		
Gars	<i>Lepisosteidae</i>		
Gobies	<i>Gobiidae</i>		
Green sunfish	<i>Lepomis cyanellus</i>		
Ide	<i>Leuciscus idus</i>		
Indian carp	<i>Cirrhinus mrigala, Catla catla and Labeo rohita</i>		
Largemouth bass	<i>Micropterus salmoides</i>		
Loaches	<i>Misgurnus</i>		
Mosquitofish	<i>Gambusia affinis</i>		
Northern pike	<i>Esox lucius</i>		
Northern snakehead	<i>Channa argus</i>		
Nutria	<i>Myocastor coypus</i>		
Pike perch zander	<i>Sander lucioperca</i>		
Plains killifish	<i>Fundulus zebrinus</i>		
Rainbow trout	<i>Oncorhynchus mykiss</i>		
Red shiner	<i>Cyprinella lutrensis</i>		

Table 4: Pathogenic Microbial Organisms of Concern

Common Name	Scientific Name
Heterospories	<i>Heterosporis sp.</i>
Infectious salmon anemia virus	<i>N/A</i>
Viral hemorrhagic septicemia virus	<i>N/A</i>
Whirling disease	<i>Myxobolus cerebralis</i>
Cyanobacteria	<i>multiple</i>

Conclusions

Early in the research process it became apparent that the scope of the initial proposal was too narrow. Reclamation facilities are impacted by nuisance species as well as invasive species, and by terrestrial organisms like plants and animals as well as aquatic organisms. Also, creating a “ranking” of species of concern would require extensive additional analysis and collaboration with other organizations and groups.

Results obtained through online searches revealed that most environmental agencies have their own lists of organisms of concern. Unsurprisingly, many of these lists contain the same organisms. Regardless of the agency, its mission, or the area of interest, an invasive aquatic organism generally has negative impacts to aquatic interests, allowing for the possibility of future inter-agency collaborative efforts.

Several organisms of concern to Reclamation have already been investigated yet remain potential threats due to lack of control options, lack of funding to pursue research, and resigned acceptance of an organism’s presence. These include organisms such as *Hydrilla verticillate* (hydrilla), *Salvinia molesta* (Salvinia), and *Tamarix* (salt cedar), among others.

Due to an inability to predict the future and poor understanding of life span, spread patterns, population dynamics, and specific environmental requirements for each organism, it is not feasible to provide a ranked order of organisms or to isolate a single specific organism as the “most” critical. A more productive approach is to review existing literature and monitor spread and impact of a variety of species with the goal of being prepared should one population explode.

Broader input from Regions and Area offices, and people working in the field, is necessary to determine which species are having the greatest impact. Only with widespread communication among those working in Reclamation facilities will the true impacts of invasive organisms, both aquatic and terrestrial, be understood.

Further research into lesser known organisms is critical to understanding habitat requirements, potential impacts, control methods, and spread patterns. Additionally, investigations into invasive and nuisance species in the eastern US that affect similar infrastructure would be beneficial as a potential early warning for Reclamation facilities.

The ability to effectively identify and manage potential invasive species is of significant need to Reclamation facilities and fisheries managers, particularly where Reclamation infrastructure may be at risk. Potential expansions of this project would focus on creating a resource where invasive species threats, along with the niche and known control methods, would be combined with a literature database containing information about the different species. If a new appearance or establishment occurs, this information would be readily available. In addition, it would be useful to create a document with basic identification information for the highest-threat organisms that could be shared with Reclamation staff to facilitate the reporting of any organisms that seem to be causing a problem.

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Ranking and Categorizing Aquatic Invasive Species Threatening Western US Waters

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**Funded by the Bureau of Reclamation Science and Technology
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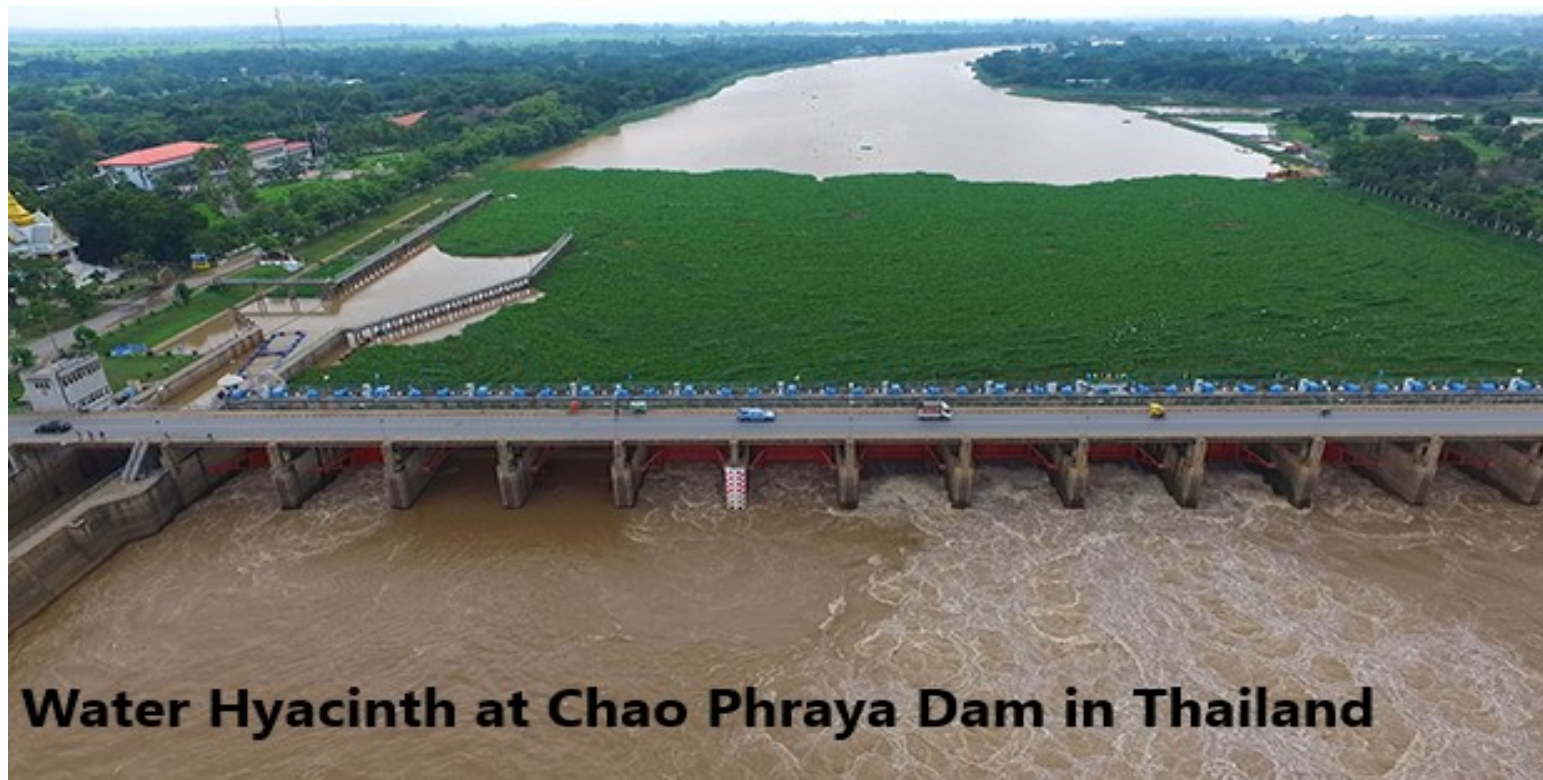
Project Summary

- Numerous aquatic invasive species exist in the US, but have not traveled into the 17 western states
- The ability to effectively manage and control these species is of urgent need to Reclamation
- This will create a resource where information on current aquatic invasive species threats, along with the niche and known control methods, may be readily available

Impacts to Reclamation

- Physical damage to infrastructure
- Water conveyance restriction
- Complications with environmental restoration
- Habitat loss/damage
- Threat to native/endangered species
- Detrimental to recreation

Final Report ST-2019-7135-01 Appendix A



Water Hyacinth at Chao Phraya Dam in Thailand

Invasive Organisms Elsewhere

Three Gorges Dam in China has identified at least 42 established invasive species since opening up a lock enabling large vessel passage in 2003. ¹



Invasive Organisms Elsewhere: Great Lakes

- The Great Lakes have sustained ecological damage due to establishment of 180+ invasive and non-native species ²
- Aggregate costs to the Great Lakes region addressing aquatic invasive species is likely over \$100 million per year ³



How Organisms can Adversely Impact Reclamation

- **Burrowing (seepage and canal failure)**
- **Adherence to/colonization of hard surfaces in water**
- **Restriction of water flow**
- **Damage to equipment or structures**



Information and Lists Compiled by Other Agencies

- **National Invasive Species Council Management Plan 2016-2018**
- **Department of the Interior Invasive Species Impacts on Infrastructure**
- **US Fish and Wildlife Service Ecological Risk Screening Summaries**
- **Western Governors' Association**

Plants

- African waterweed
- Air Potato
- Alligatorweed
- Ambulia, Asian Marshweed
- Asiatic Bittersweet
- Brazilian Elodea
- Buffelgrass
- Cheatgrass
- Curly Leaf Pondweed
- Cyanobacteria/"blue-green algae"^{**}
- Didymo/Rock Snot^{**}
- Duck Weed
- Eurasian Watermilfoil
- European Water Chestnut
- Floating Primrose-Willow
- Flowering Rush
- Fountain Grass
- Giant Reed
- Giant Salvinia
- Hydrilla
- Knapweed
- Loosestrife, purple
- Melaleuca/Paperbark Tree
- Mile-A-Minute Weed
- Miramar Weed
- Mosquito fern/fairy moss
- Multiflora Rose
- Musk Thistle
- Old World Climbing Fern
- Parrotfeather
- Pepperweed
- Pickerel Weed
- Princess Tree
- Quackgrass/couch grass
- Reed Canary Grass
- Russian Knapweed
- Russian Olive
- Sacred Bamboo
- Sahara Mustard
- Saltcedar/Tamarisk
- Scotch Thistle
- Spotted Knapweed
- St Johns Wort
- Tree Tobacco
- Tree-of-Heaven
- Tropical Soda Apple
- Water Creeping Primrose
- Water Hyacinth
- Water Lettuce
- Water Spinach
- Whitetop
- Willow-herb, hairy
- Witchweed
- Yellow Flag Iris
- Yellow Floating Heart
- Yellow Star Thistle
- Yellow Toadflax

Vertebrates

Mammal

- Nutria

Amphibians

- Frog, clawed African
- Bullfrog
- Marine/Cane Toad

Fish

- Alewife
- Bass (multiple species)
- Bitterling
- Black Crappie
- Bluegill Sunfish
- Bowfin
- Brown Trout
- Bullhead, black
- Bullhead, yellow
- Burbot
- Carp (multiple species)
- Catfish (multiple species)
- Fathead minnow
- Gars

- Gobies
- Green sunfish
- Ide
- Loach
- Mosquitofish
- Northern pike
- Northern Snakehead
- Pickerel, chain
- Plains Killifish
- Rainbow Trout
- Red Shiner
- Rudd
- Ruffe, Eurasian
- Stickleback
- Threadfin Shad
- Tilapia
- Walleye
- Zander, Pike Perch



Invertebrates

- Chinese Mitten Crab
- Crayfish (multiple species)
- Amphipod, Ponto-Caspian
- Asian Shore Crab
- Asian Swamp Eel
- Asian/Clubbed Tunicate
- Asian Clam
- European Green Crab
- Hydroid, colonial
- Mussels, Quagga/Zebra
- Red Imported Fire Ants
- Shrimp, killer
- Snail, Channeled Apple
- Snail, Giant African Land
- Snail, Giant Rams-horn
- Snail, European valve
- Snail, New Zealand Mud
- Tawny Crazy Ant
- Veined Rapa Whelk
- Water Flea, Fishhook
- Water Flea, Spiny



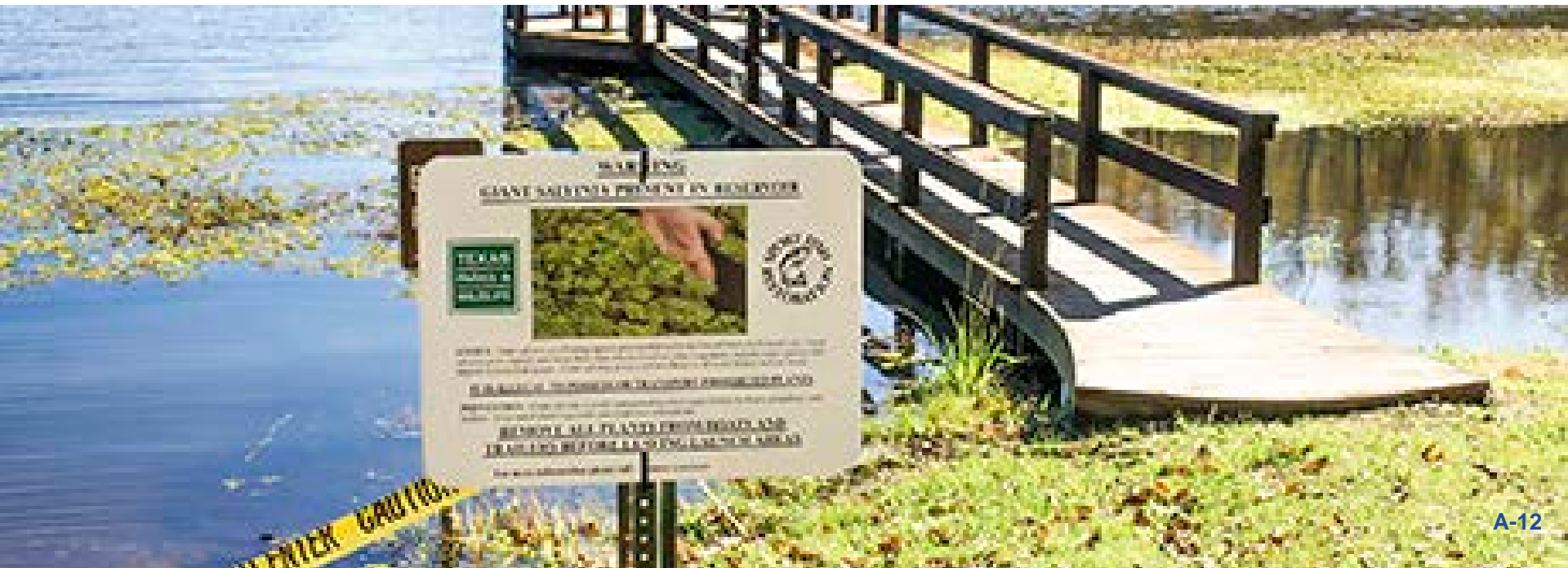
Top Organisms of Concern

- Zebra/Quagga mussels
- Giant Salvinia
- Water Hyacinth
- Saltcedar
- Asian Carp
- Nutria
- Burrowing Crayfish
- Chinese Mitten Crab
- Red Imported/Tawny Crazy Ants

Organism of Concern: Giant Salvinia

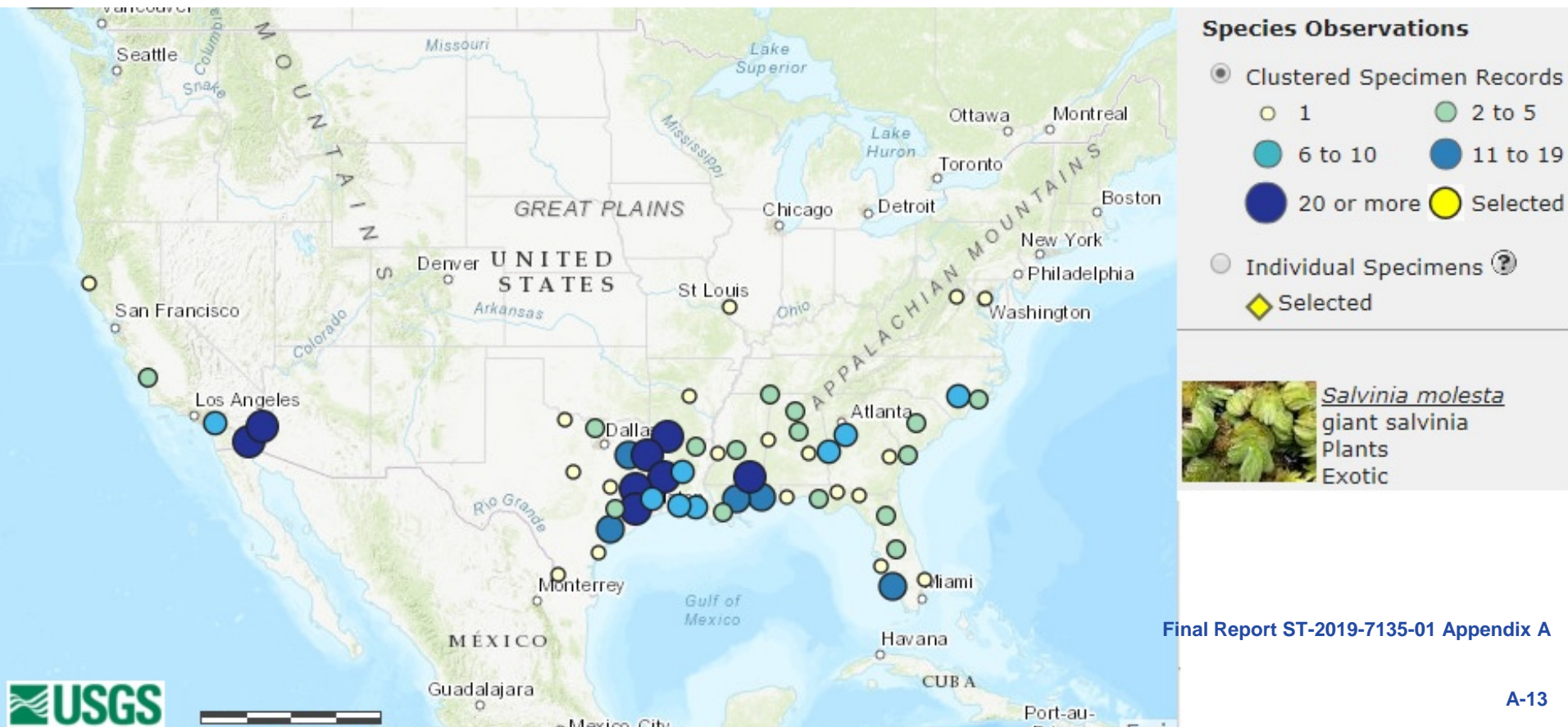
- Impacts to recreation, flood mitigation, and irrigation
- Clogs waterways
- Blocks sunlight
- Prevents air exchange

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Organism of Concern: Giant Salvinia

Distribution in US as reported by US Geological Survey (USGS)



Organism of Concern: Nutria

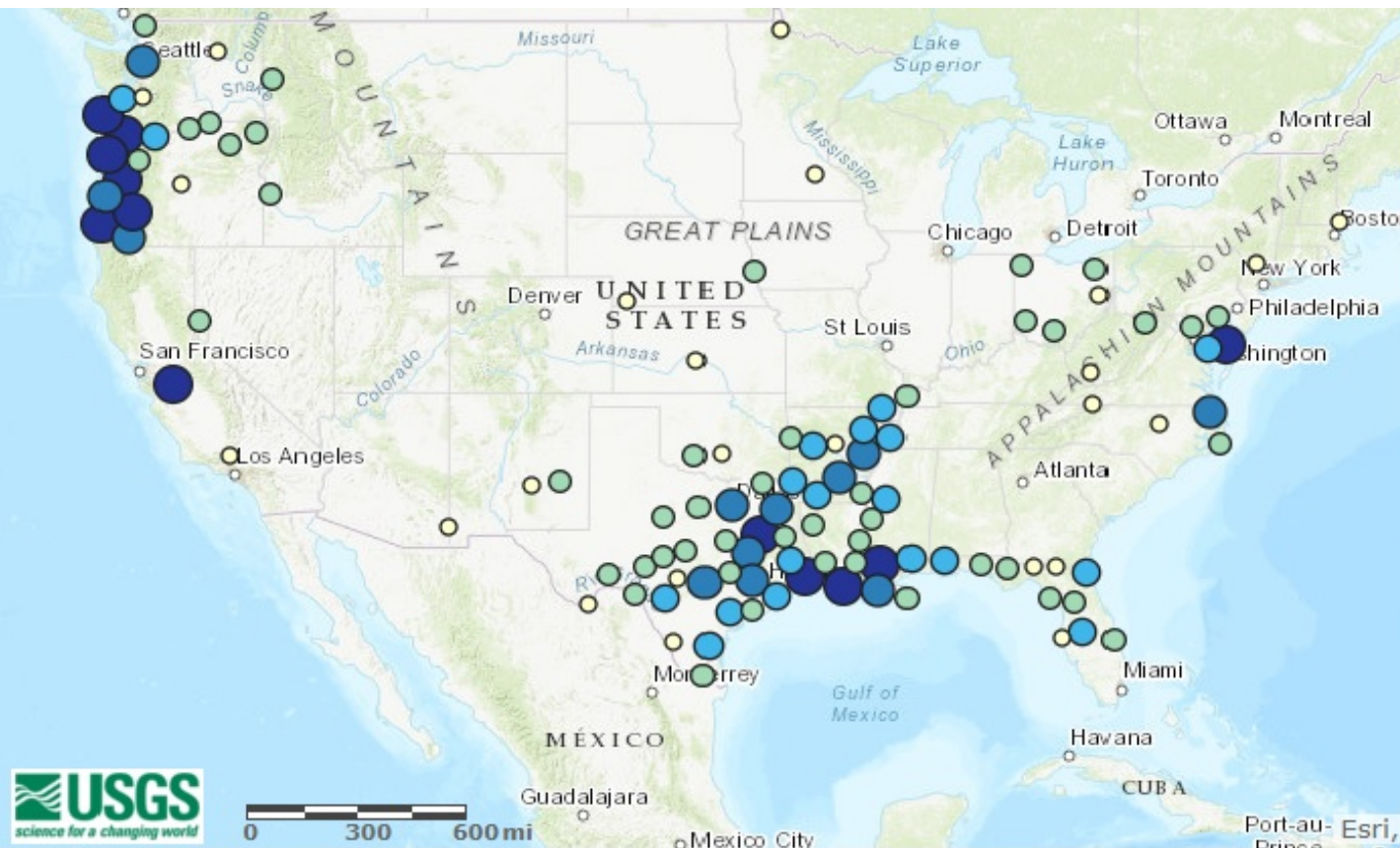
- **Burrowers – cause erosion**
- **Prolific breeders**
- **Have already caused significant damage in Southeast US**



Organism of Concern: Nutria

Distribution in US

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Species Observations

- Clustered Specimen Records
 - 1
 - 2 to 5
 - 6 to 10
 - 11 to 19
 - 20 or more
 - Selected
- Individual Specimens (?)
- ◆ Selected



Myocastor coypus
nutria
Mammals
Exotic

Organism of Concern: Chinese Mitten Crab

- Burrowers that may also clog fish screens and impede water delivery during their mass migrations
- Can be found in both salt and fresh waters
- Capable of walking hundreds of miles

WANTED

DEAD OR ALIVE



INVASIVE SPECIES: Chinese Mitten Crab

The key identifying characteristic are “furry” claws. All adults and juveniles over an inch long have furry white-tipped claws that are equal in size. They have light brown to olive green round bodies (carapaces) that are 3 to 4 inches wide in adults. The carapace is smooth and has 4 lateral spines; the fourth spine may be small. Between the eyes sits a U-shaped notch. Mitten crabs can be found in both freshwater and saltwater environments.

WHAT TO DO IF I FIND A CRAB?

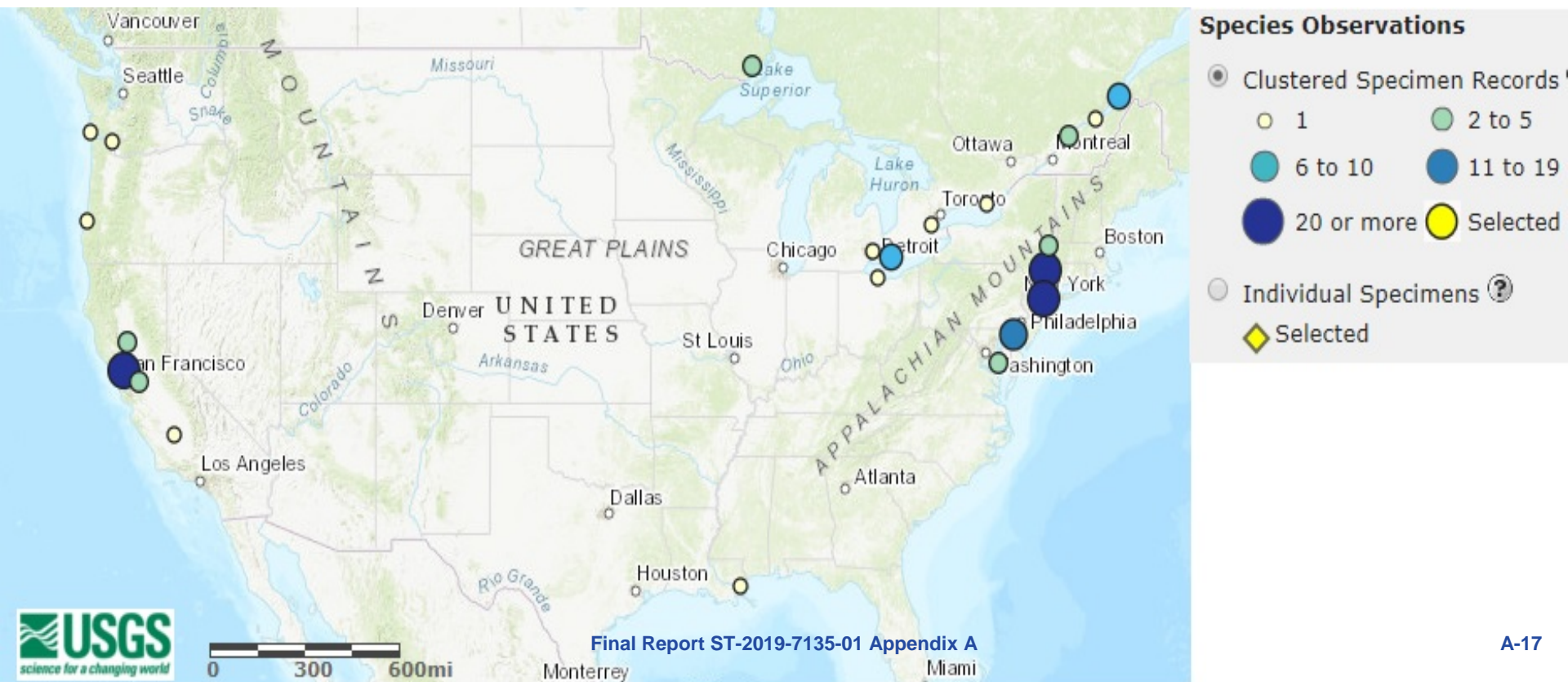
DO NOT THROW IT BACK ALIVE!

Freeze the animal, keep on ice, or preserve it in rubbing alcohol, as a last resort.
Note the precise location where the animal was found & take multiple close-up photos!

Upload photos to <http://mittencrab.nisbase.org/> for identification.
Include your contact information with photo!

Organism of Concern: Chinese Mitten Crab

Distribution in US



Did You Know?

- Giant African Land Snails can eat stucco and concrete?
- Tawny Crazy Ants eat electrical wiring?
- The Pepperweed plant can increase soil erosion?
- Impoundments (reservoirs) are more susceptible to invasion by non-native species?



What Next?

- How can this project best serve Reclamation as a whole?
- Develop an info sheet with species' photos and identifying characteristics to provide to staff?
- Notify rdles@usbr.gov of any potential pests or sightings



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**Hydraulics Investigations and Laboratory Services
Technical Service Center, Denver, Colorado**

RECLAMATION
Managing Water in the West

Resources

3 Gorges Dam Photo <http://www.ultimatescience.org/three-gorges-dam-affecting-earths-rotation/>

Great Lakes Photo <https://www.mprnews.org/story/2017/03/06/great-lakes-mayors-warn-against-cut-to-ecological-initiative>

Canal Operation and Maintenance: Animals https://www.usbr.gov/assetmanagement/docs/Canal_Animals.pdf

Burrow photo <https://en.wikipedia.org/wiki/Burrow#/media/File:C0136-bird-burrows.jpg>

Chinese Mitten Crab photo <https://www.chesapeakebaymagazine.com/baybulletin/2018/6/25/wanted-invasive-mitten-crab-lurking-in-the-bay>

Fire Ant photo <http://www.lovepowerx.com/creature/red-imported-fire-ant/>

Water flea photo <https://nl.wikipedia.org/wiki/Daphnia>

Asian carp photo <https://u.osu.edu/extensioncd/tag/asian-carp/>

Xiong et al 2018 http://www.reabic.net/journals/bir/2018/2/BIR_2018_Xiong_etal.pdf

Salvinia distribution map <https://nas.er.usgs.gov/viewer/omap.aspx?SpeciesID=298>

Nutria distribution map <https://nas.er.usgs.gov/viewer/omap.aspx?SpeciesID=1089>

Chinese Mitten Crab distribution map <https://nas.er.usgs.gov/viewer/omap.aspx?SpeciesID=182>

Economic data https://www.andersoneconomicgroup.com/Portals/0/upload/AEG%20-%20AIS%20Impact_%209-20-2016%20Public%20new.pdf

Great Lakes NOAA https://www.regions.noaa.gov/great-lakes/index.php/great_lakes-restoration-initiative/invasive-species/

Water Hyacinth on Dam <https://www.bangkokpost.com/news/general/1092092/chao-phraya-dam-being-cleared-of-water-hyacinth>

