**Title:** Invasive Mussel Literature Resource  

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Mission Statements

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.

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.

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Acknowledgements

The Science and Technology Program, Bureau of Reclamation, sponsored this research.
Peer Review

Bureau of Reclamation
Research and Development Office
Science and Technology Program

Final Report ST-2021-19138-01

Invasive Mussel Literature Resource

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Prepared by: Yale Passamaneck
Biologist, Ecological Research Laboratory, Hydraulic Investigations and Laboratory Services Group, 86-68560

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Peer Review by: Sherri Pucherelli
Biologist, Ecological Research Laboratory, Hydraulic Investigations and Laboratory Services Group, 86-68560

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Acronyms and Abbreviations

Reclamation    Bureau of Reclamation
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Executive Summary

A large and growing body of literature has been generated regarding invasive dreissenid (quagga and zebra) mussels since they were first detected in the Great Lakes over 30 years ago. Given the impact of invasive mussels in the Lower Colorado River, and the continuing threat of their introduction and spread in other regions, access to relevant scientific results and other literature is critical for Reclamation operations and planning. Assessment of previous work on dreissenids can highlight what has, and has not, already been learned, and can help to avoid potentially costly duplication of effort. Because literature on invasive mussels is dispersed, much of it in reports, theses, presentations, and other documents outside the peer-reviewed literature, relevant information may escape the attention of Reclamation researchers and managers. A previous project funded by Reclamation’s Science and Technology Program aggregated a wide variety of invasive mussel literature into a central repository where it was organized and made accessible. The current project has built upon this previous effort, surveying and incorporating newly published or available literature to maintain the relevance and utility of this resource.
Main Report

Methods

Literature on dreissenid mussel control was drawn from a wide variety of sources, including search engines, literature databases, and professional social networking tools, such as Google Scholar (scholar.google.com), CiteSeerX (citeseer.ist.psu.edu), and ResearchGate (www.researchgate.net). Reports and theses were also obtained from institutional and academic websites, and online databases. Because a substantial portion of the research on mussel control has not been published in peer-reviewed journals or books, this study also incorporated technical reports, theses, conference proceedings, and presentations, to provide the broadest possible survey of relevant work.

This study focused on literature for which full-text PDFs, and other source documents, could be obtained, so that methods and results could be directly evaluated. All literature was organized using the open-source reference management software Zotero (www.zotero.org). Each reference was added to the Zotero library as a separate item. Items were annotated with source data to facilitate citation and generation of bibliographies. Relevant keyword tags were added to each item to aid in identification of items of interest based on subject area. PDFs or other source documents were attached to each item as available.

For Reclamation operations, the quagga mussel (*Dreissena rostriformis bugensis*) is the primary species of concern. However, the majority of literature to date has focused on the zebra mussel (*Dreissena polymorpha*), due to its earlier appearance in North America and its broader geographic spread in the United States. Therefore, literature on both species was collected and included in the Zotero library.

Results, Conclusions and Future Prospects

In this project the Zotero library for invasive mussel literature has been increased from 390 entries from the previous project (documented in Final Report ST-2018-1868-01; www.usbr.gov/research/projects/detail.cfm?id=1868) to a total of 658 entries in the current project. Topics covered by literature in this collection include the introduction and spread of zebra and quagga mussels, physiology, habitat suitability, economic and ecological impacts, detection and monitoring methods, molecular biology and genomics, response strategies following initial detection of mussels, control techniques, and ecotoxicology.

The Zotero library generated for this project is searchable, allowing identification of literature relevant to topics of interest. Identification of relevant items is further aided by the inclusion of 271 unique tags, which can be used to rapidly identify items of interest related to a given topic. PDFs and other source documents are attached to nearly all references included in the library. The generated library and associated document files have been exported into a variety of library file
formats, including BibTex, EndNote XML, RIS, Zotero RDF. These exported libraries allow importation into reference management software programs including Mendeley (www.mendeley.com), Zotero (www.zotero.org), ReadCube (www.readcube.com), and EndNote (endnote.com), among others. All these programs support direct citation of references and generation of bibliographies within Microsoft Word, greatly simplifying the inclusion of references within reports, manuscripts, and other documents.

All reference included in the literature library are listed in the References section below. This final report and the exported reference libraries have been added to the Reclamation Information Sharing Environment (RISE; data.usbr.gov) under Catalog ID 4511. Project data have also been added to the Technical Service Center’s Science and Technology shared drive folder (Z:\DO\TSC\Jobs\DO\NonFeature\Science and Technology).

It is expected that the reference library generated in this project will continue to be a valuable resource for Bureau of Reclamation researchers and managers interested in variety of topics regarding invasive dreissenid mussels. Maintaining and updating this resource will be important to ensuring its ongoing utility for researcher and managers. Looking forward, the Ecological Research Laboratory plans to continue development of this literature library as a regular part of ongoing operations in invasive mussel early detection, monitoring, and control.
References


California Sea Grant Program. (2012). *Quagga and zebra mussel eradication and control workshop* [Workshop report]. California Sea Grant Program and the University of California Cooperative Extension.


Dept. of Biology, Universitat de Girona, Spain, Peñarrubia, L., Viñas, J., Dept. of Biology, Universitat de Girona, Spain, Sanz, N., Dept. of Biology, Universitat de Girona, Spain, Smith, B. L., Dept. of Natural Sciences, Brigham Young University, Hawaii, USA, Alvarado Bremer, J. R., Dept. of Wildlife and Fisheries Sciences, Texas A&M University, USA, Pla, C., Dept. of Biology, Universitat de Girona, Spain, Vidal, O., & Dept. of Biology, Universitat de Girona, Spain. (2019). SNP identification and validation in two invasive species: Zebra mussel (*Dreissena polymorpha*) and Asian clam (*Corbicula fluminea*). *Animal Biodiversity and Conservation, 42*(1), 65–68. https://doi.org/10.32800/abc.2019.42.0065


FishPro. (2005). *Feasibility study to limit the spread of zebra mussels from Ossainnamakee Lake* [Consultant’s Report]. Minnesota Department of Natural Resources.


Greene, M. (2021a). An estimated 300 trillion invasive mussels blanket Lake Michigan. Eradication may be impossible, but small-scale removal efforts could be the answer. *Chicago Tribune*.

Greene, M. (2021b). Scientists study the genetics of invasive mussels seeking ways to turn off genes that allow them to spread and survive. *Chicago Tribune*.


Guidi, P., Bernardeschi, M., Palumbo, M., Genovese, M., Scarcelli, V., Fiorati, A., Riva, L., Punta, C., Corsi, I., & Frenzilli, G. (2020). Suitability of a cellulose-based nanomaterial for the remediation of heavy metal contaminated freshwaters: A case-study showing the recovery of cadmium induced DNA integrity loss, cell proliferation increase, nuclear morphology and chromosomal alterations on *Dreissena polymorpha*. *Nanomaterials, 10*(9), 1837. [https://doi.org/10.3390/nano10091837](https://doi.org/10.3390/nano10091837)


may have significant impacts on lake ecosystems. *Journal of Great Lakes Research, 44*(4), 650–659. https://doi.org/10.1016/j.jglr.2018.05.010


https://doi.org/10.1371/journal.pone.0240996

Mann, R. (2010). *Economic risk associated with the potential establishment of zebra and quagga mussels in the Columbia River Basin.* 82.


https://doi.org/10.3391/ai.2021.16.1.10

https://doi.org/10.1002/ece3.4985

https://doi.org/10.1038/s41598-021-82205-4

https://doi.org/10.1007/BF01128739

https://doi.org/10.1007/BF01128738


https://doi.org/10.1111/j.1472-4642.2010.00693.x

https://doi.org/10.1007/s00248-020-01642-2


Minguez, L., Devin, S., Molloy, D. P., Guérold, F., & Giambérini, L. (2013). Occurrence of zebra mussel parasites: Modelling according to contamination in France and the USA. Environmental Pollution, 176, 261–266. https://doi.org/10.1016/j.envpol.2013.01.031


Invasive Mussel Literature


Otts, S., & Nanjappa, P. (2014). *Preventing the spread of aquatic invasive species by recreational boats: Model legislative provisions & guidance to promote reciprocity among state watercraft inspection and decontamination programs* (p. 44). National Sea Grant Law Center.


Peñarrubia, L., Alcaraz, C., Vaate, A. bij de, Sanz, N., Pla, C., Vidal, O., & Viñas, J. (2016). Validated methodology for quantifying infestation levels of dreissenid mussels in environmental DNA (eDNA) samples. *Scientific Reports, 6*, 39067. https://doi.org/10.1038/srep39067


Richardson, T., & Richardson, S. (n.d.). *Battle of the Bads!: A Report on the Most Harmful Nonindigenous Aquatic Species Within the Contiguous States West of the 100th Meridian*. Wildlife Forever.


SeaGrant Law Center. (2021). *Preventing the Spread of Quagga and Zebra Mussels to the Columbia River Basin and Pacific Northwest via Interstate Boat Sales* (p. 19).


Smythe, A. G., & Dardeau, E. A. (1999). Overview of electrical technologies for controlling dreissenids, with emphasis on pulse-power systems (Technical Note ZMR-3-22). U.S. Army Corps of Engineers. [http://acwc.sdp.sirsi.net/client/es_ES/default/index.assetbox.assetactionicon.view/1005158?rm=ZEBRA+MUSSEL+R0%7C7C%7C%7C%7C%7C%7C%7C%7C%7C%true](http://acwc.sdp.sirsi.net/client/es_ES/default/index.assetbox.assetactionicon.view/1005158?rm=ZEBRA+MUSSEL+R0%7C7C%7C%7C%7C%7C%7C%7C%7C%7C%true)


Western Regional Panel on Aquatic Nuisance Species. (2020b). *Updated recommendations for the quagga and zebra mussel action plan for Western U.S. waters (QZAP 2.0)*. Western Regional Panel on Aquatic Nuisance Species.


