Predictive Modeling of Dreissenid Mussel Invasion Risk

Need to Predict Mussel Invasions

Two invasive species of dreissenid mussels, zebra and quagga mussels, are spreading across the United States, interfering with the operation of water supply and delivery facilities and adding to operational expenses. Mussels clog pipes, add weight to gates, and alter the ecology of infested reservoirs which can impact sport fisheries and recreational opportunities (Figure 1).

Figure 1. Example: cross-section of a pipe showing a buildup of zebra mussels

Preventing initial introduction and rapidly responding to early detections are the most effective means of stopping the spread of the mussels. The Bureau of Reclamation (Reclamation) and our partners have limited funding for early detection, prevention, and mussel control efforts. Accordingly, there is a need to prioritize high-risk locations and maximize the effectiveness of mussel control options.

Invasive mussels have been spread across the United States by recreational boaters since these species were introduced to the Great Lakes in the 1980s. An introduction of mussels does not always lead to an infestation if environmental conditions are not suitable, but predicting which waterbodies are most at risk is challenging. This Internal Applied Science project developed a model to predict the spread of the invasive mussels, supporting Reclamation efforts to identify high-risk locations and prioritize funding.

Modeling Habitat Suitability and Boater Movement

Reclamation's Ecological Research Laboratory at the Technical Service Center worked with the U.S. Army Corps of Engineers' Engineer Research and Development Center to develop a model to predict the spread of invasive mussels. The new model builds on an existing model and utilizes an open-source, multi-agent programmable modeling environment called Netlogo. The model is unique because it combines a constrained gravity model with a habitat suitability index to predict boater movement and resulting infestations.

The original model included the ability to manipulate several parameters, including the percentage of boats leaving an infested waterbody with mussels onboard, the percentage of mussels that survive transport to a new location, and the number of boats that need to arrive with living mussels to cause an infestation. This project improved the original model by adding additional waterbodies (Figure 2) and by collecting water quality data (pH and calcium) for over 300 locations from the National Water Quality Portal, Ambient Water Quality Monitoring System, Reclamation and state offices, and published literature. The new model includes water quality data from 189 Reclamation waterbodies and 471 total waterbodies.

The new model also includes improved capability to quantify the number of boaters moving between waterbodies using actual boater visitation numbers collected by Colorado Parks and Wildlife. An additional model parameter was created to explore the effects of management strategies on mussel spread, and the model interface was reorganized with instructional notes to help future users.

The model was executed with various combinations of model parameters for durations of 1, 2, or 3 years. The simulations involved 240 model runs created for each duration.

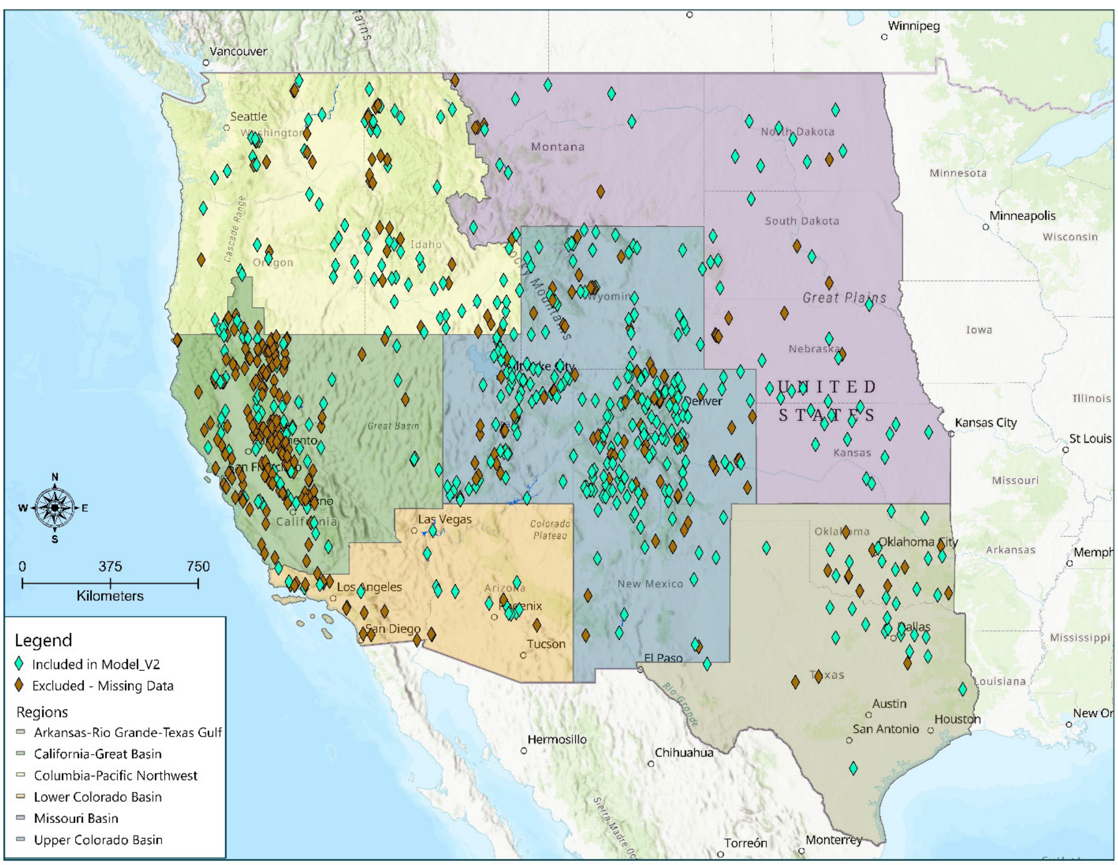

Figure 2. Map of waterbodies included in the model

Infestation Likelihood	Reclamation Waterbodies That Became Infested After 3-Year Modeled Duration
>90%	American Falls Reservoir (ID), Deer Creek Reservoir (UT), Strawberry Reservoir (UT), Theodore Roosevelt Lake (AZ)
85% to 90%	Flaming Gorge Reservoir (UT-WY), Lahontan Reservoir (NV), Lake Walcott (ID), Palisades Reservoir (ID), Pyramid Lake (NV), Rye Patch Reservoir (NV), Willard Bay Reservoir (UT)
75% to 85%	Alcova Reservoir (WY), Bartlett Reservoir (AZ), Bighorn Lake (WY-MT), Boysen Reservoir (WY), Caballo Reservoir (NM), Canyon Ferry Lake (MT), Cheney Reservoir (KS), Clear Lake Reservoir (CA), Echo Reservoir (UT), Elephant Butte Reservoir (NM), Fontenelle Reservoir (WY), Hungry Horse Reservoir (MT), Jordanelle Reservoir (UT), Kirwin Reservoir (KS), Lake Thunderbird (OK), Navajo Reservoir (CO-NM), Nelson Reservoir (MT), Ocean Lake (WY), Pathfinder Reservoir (WY), Pineview Reservoir (UT), Scofield Reservoir (UT), Seminoe Reservoir (WY), Shasta Lake (CA), Starvation Reservoir (UT), Tom Steed Reservoir (OK), Tule Lake (CA), Waconda Lake (KS)
50% to 75%	Angostura Reservoir (SD), Belle Fourche Reservoir (SD), Blue Mesa Reservoir (CO), Choke Canyon Lake (TX), Clark Canyon Reservoir (MT), Currant Creek Reservoir (UT), East Canyon Reservoir (UT), East Park Reservoir (CA), Edward Arthur Patterson Lake (ND), El Vado Reservoir (NM), Enders Reservoir (NE), Fort Cobb Reservoir (OK), Franklin D Roosevelt Lake (WA), Fresno Reservoir (MT), Glendo Reservoir (WY), Gray Reef Reservoir (WY), Green Mountain Reservoir (CO), Guernsey Reservoir (WY), Harry Strunk Lake (NE), Helena Valley Reservoir (MT), Heron Reservoir (NM), Hugh Butler Lake (NE), Huntington (Mammoth) Reservoir (UT), Hyrum Reservoir (UT), Jamestown Reservoir (ND), Joes Valley Reservoir (UT), Keith Sebelius Lake (KS), Keyhole Reservoir (WY), Lake Berryessa (CA), Lake Cachuma (CA), Lake Elwell (MT), Lake Lowell (ID), Lake Nighthorse (CO), Lake Owyhee (OR), Lake Tschida (ND), Lemon Reservoir (CO), Los Banos Reservoir (CA), Lost Creek Reservoir (UT), Lovewell Reservoir (KS), McPhee Reservoir (CO), New Melones Lake (CA), Newton Reservoir (UT), Pueblo Reservoir (CO), Red Fleet Reservoir (UT), Ridgway Reservoir (CO), Ririe Reservoir (ID), Rockport Lake (UT), San Luis Reservoir (CA), Shadehill Reservoir (SD), Steinaker Reservoir (UT), Stony Gorge Reservoir (CA), Sumner Lake (NM), Swanson Lake (NE), Upper Klamath Lake Reservoir (OR), Warm Springs Reservoir (OR), Webster Reservoir (KS)
25% to 50%	Brantley Reservoir (NM), Calamus Reservoir (NE), Crawford Reservoir (CO), Deerfield Lake (SD), Island Park Reservoir (ID), Jackson Gulch Reservoir (CO), Lake Casitas (CA), Lake Granby (CO), Little Wood River Reservoir (ID), New Johns Lake (ND), Pactola Reservoir (SD), Paonia Reservoir (CO), Pilot Butte Reservoir (WY), Pineview Reservoir (UT), Ruedi Reservoir (CO), Thief Valley Reservoir (OR), Twitchell Reservoir (CA), Vega Reservoir (CO), Willow Creek Reservoir (MT)
0% to 25%	Cold Springs Reservoir (OR), Deaver Reservoir (WY), East Newton Lake (WY), Prineville Reservoir (OR), Rifle Gap Reservoir (CO), Silver Jack Reservoir (CO), Unity Reservoir (OR), West Newton Lake (WY)
Not Infested	Agate Reservoir (OR), Anderson Ranch Reservoir (ID), Arrowrock Reservoir (ID), Banks Lake (WA), Beulah Reservoir (OR), Black Canyon Reservoir (ID), Boca Reservoir (CA), Bumping Lake (WA), Carter Lake Reservoir (CO), Cle Elum Lake (WA), Crane Prairie Reservoir (OR), Deadwood Reservoir (ID), East Portal Reservoir (CO), Emigrant Lake (OR), Flatiron Reservoir (CO), Folsom Lake (CA), Grand Lake (CO), Grassy Lake (WY), Haystack Reservoir (OR), Henry Hagg Lake (OR), Horsetooth Reservoir (CO), Howard Prairie Lake (OR), Hyatt Reservoir (OR), Jackson Lake (WY), Keechelus Lake (WA), Keswick Reservoir (CA), Lake Cascade (ID), Lake Como (MT), Lake Estes (CO), Lake Tahoe (CA-NV), Little Kachess Lake (WA), Marys Lake (CO), Mason Reservoir (OR), McGee Creek Lake (OK), McKay Reservoir (OR), Meeks Cabin Reservoir (WY), Millerton Lake (CA), Moon Lake (UT), Mount Elbert Forebay (CO), ONeill Forebay (CA), Pinewood Lake (CO), Platoro Reservoir (CO), Rimrock Lake (WA), Shadow Mountain Lake (CO), Sly Creek Reservoir (CA), Stampede Reservoir (CA), Stateline Reservoir (UT), Taylor Park Reservoir (CO), Trinity Lake (CA), Turquoise Lake (CO), Twin Lakes (CO), Upper Stillwater Reservoir (UT), Vallecito Reservoir (CO), Whiskeytown Lake (CA), Wickiup Reservoir (OR)

Table 1. Likelihood of infestation for Reclamation waterbodies after 3-year modeled duration

Key Results

Results for the 189 Reclamation waterbodies in the model were compiled to determine a likelihood of infestation for each location. The results for the 3-year duration are shown in Table 1, above.

In all three durations, the first waterbodies to become infested were Theodore Roosevelt Lake (AZ) and Utah Lake (UT). Both waterbodies are close to established mussel populations and both have large areas which should make them attractive to boaters. These waterbodies became infested in over 90 percent of all runs. Note that Utah Lake is not listed in Table 1 because it is not a Reclamation waterbody.

During the 2-year runs, Bear Lake (ID-UT) and Strawberry Reservoir (UT) became infested in over 90 percent of model runs. In the 3-year runs, American Falls Reservoir (ID) and Deer Creek Reservoir (UT) also exceeded the 90 percent threshold. Bear Lake is a natural lake and so is not included in the table of Reclamation waterbodies.

As shown in Table 1, model results indicated that the following Reclamation waterbodies were infested more than 85 percent of the time for the 3-year duration: Flaming Gorge Reservoir (UT-WY), Lahontan Reservoir (NV), Lake Walcott (ID), Palisades Reservoir (ID), Pyramid Lake (NV), Rye Patch Reservoir (NV), and Willard Bay Reservoir (UT).

Project Benefits and Next Steps

The predictive model will benefit Reclamation and our state, Tribal, and other partners by helping facility operators and natural resource managers direct limited resources to reduce the spread of invasive dreissenid mussels. Quagga and zebra mussels cause economic and ecological damage when they infest a new waterbody; preventing initial infestation can reduce these impacts.

Additional analysis of the model results is required to determine if current monitoring programs are appropriate or need to be modified. It may be possible to reduce some monitoring efforts and redirect funds to a different location.

The initial signs of mussel infestation have also recently been documented at two waterbodies which had a modeled likelihood of infestation below 50 percent. Additional investigation would be required to determine if these two waterbodies should have ranked higher or if the new infestations are more random occurrences.

This model improved Reclamation's ecological modeling capacity and explored the utility of the modeling environment. Although this project significantly expanded the original mussel risk model and produced results that should be useful to Reclamation and our partners, additional refinements could be made. There are still almost 300 waterbody locations that do not have adequate pH and calcium data to be used in the model. Finding sufficient water quality information for many waterbodies was a challenge. Although multiple databases exist, they are often difficult to navigate and lack completeness. Boater visitation numbers from other states that track inspections could also be used to refine the boater regression model.

Additional Information

Useful Links for Applied Science:

https://www.usbr.gov/watersmart/appliedscience/index.html

WaterSMART Website:

https://www.usbr.gov/watersmart

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