RECLAMATION Managing Water in the West

Spring 2014
Research and
Development Office
Bulletin 2014-04

The Knowledge Stream
Research Update

Understanding How Mussels Attach to Surfaces

Molecular-level insight to develop durable coatings that prevent mussel attachment

Bottom Line

This research project highlighted advances in the mussel adhesion literature.

Better, Faster, Cheaper

Many costs are associated with mussel attachment to Reclamation structures. Preventing this attachment is one means to reduce impacts to flows, water delivery, and hydropower production. This foundational knowledge will be used to develop durable coatings that prevent mussel attachment.

Principal Investigator

Bobbi Jo Merten
Chemist
Materials Engineering and Research Laboratory
Technical Service Center
303-445-2380
bmerten@usbr.gov

Research Office Contact

Joe Kubitschek
Invasive Mussels Research Coordinator
303-445-2148
jkubitschek@usbr.gov

Problem

Invasive mussel species, notably quagga mussels, are spreading into Reclamation's reservoirs and rivers in the Western United States. Their rapid and extensive colonization impacts operation and maintenance (O&M) of water storage, water delivery, and hydropower structures and systems. Furthermore, their presence also affects recreational usage and aquatic ecosystems. Once adult mussels settle and attach to a surface, they are very difficult to remove. Reclamation has evaluated commercial coatings that can prevent mussel attachment, such as anti-fouling and foul-release systems. Foul-release coatings were developed for marine applications and have proven to prevent mussel attachment. These coatings are typically soft silicone materials and can be easily damaged. Reclamation's structures require tough coatings that can withstand impacts from woody debris, scour, and other hazards lurking in reservoirs and rivers.

Silicone product that prevents mussel attachment. Photograph taken at Parker Dam field test site in Arizona/ California. During the semi-annual evaluation.

Solution

Understanding mussels' unique underwater attachment mechanism can provide a treasure trove of research breakthroughs in medicine and other scientific fields. National Institute of Health research grants have led to the characterization of the mussel's adhesive and cohesive proteins—a naturally occurring glue that cures underwater. The goal is to reproduce these materials or processes for biomedical applications. These research efforts have created a wealth of information and advanced theories in the mussel attachment mechanism.

This Reclamation Science and Technology Program research project reviewed advancements in understanding how mussels adhere to almost any underwater surface.

— continued

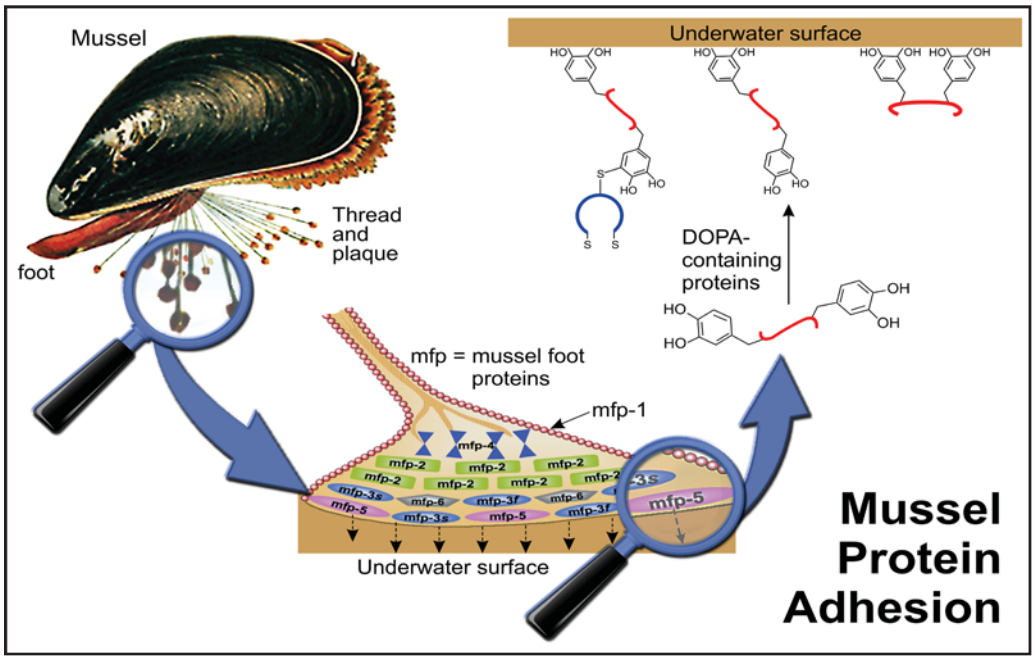
— continued

Materials engineers and coatings researchers reviewed the protein chemistry and adhesion mechanism of mussel species. This knowledge has been applied to the evaluation of methods or materials, which may effectively discourage mussel attachment. Summarizing these insights is the cornerstone to the successful development of new materials.

Conclusions and Applications

While each invasive mussel species has slightly different amino acid sequences and molecular weights, the attachment chemistry and process is similar across all mussel species. Research has revealed that the mussel's attachment process, which takes about 5 minutes, combines chemical adhesion and mechanical interlocking to form these characteristically strong bonds. The technical aspects of this process, with a view to preventing mussel attachment on Reclamation's infrastructure, will be summarized and published in the forthcoming book, Biology and Management of Invasive Quagga/Zebra Mussels in the Western United States as chapter, "Mussel Byssus and Adhesion Mechanism, Exploring Methods for Preventing Attachment."

To attach to a surface, the floating mussel extends its foot from within the shell and places it onto the surface. A protein solution is secreted through the foot to form all the necessary anchoring components: the thread (thin filament) and the plaque (disc-shaped pad). Here, the thread is analogous to a boat anchor rope, while the plaque is firmly attached to a surface as the anchor itself. The other end of the thread is secured to the mussel body—the boat in this analogy. Following this 5-minute cure, the mussel lifts its foot to reveal the new anchorage point. The process is repeated to form additional attachments.



The adhesive proteins (mussel glue) used at the plaque/surface interface are of most interest to Reclamation coating researchers. This mussel glue layer is formed from low molecular weight proteins. These proteins contain high concentrations of the amino acid protein 3,4-dihydroxyphenylalanine (Dopa), which is key to the animal's wet adhesion mechanism. Dopa forms strong, bidentate hydrogen bonds as well as covalent bonds with metals. These low molecular weight proteins easily penetrate into the surface microcracks and topography to provide mechanical interlocking where additional chemical bonding sites also become available.

"Revealing the mystery of their underwater adhesion can be the key to new coatings, materials, or technologies that may significantly reduce or prevent the rate of attachment, which is needed to sustain the reliability of Reclamation operations."

Bobbi Jo Merten
Chemist, Reclamation's Technical Service Center

Future Plans

Advances in polymer synthesis, coatings chemistry, and formulation are gearing up to provide a durable foul-release coating that prevents mussel attachment. This is a much-needed tool for Reclamation O&M in order to combat growing mussel infestations and related challenges. Reclamation is partnering with other research organizations and private companies to use insights gained in this research project to develop durable foul-release coatings or materials.

More Information

www.usbr.gov/research/projects/detail.cfm?id=7419