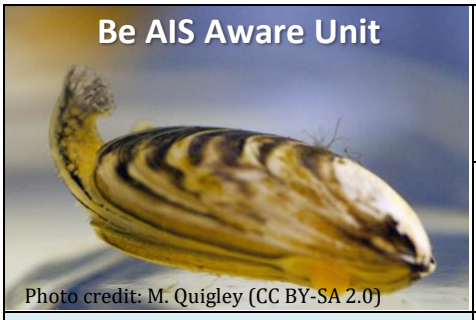


Photo credit: M. Quigley (CC BY-SA 2.0)

Mapping AIS Mayhem

Do you ever wonder why some invasive species can spread faster than others?

Grade Level
Middle School

Subject Areas
Life Science, Environmental Science, Ecology, and Human Impacts

Key Topics
Aquatic invasive species, pathways of introduction, methods of dispersal

Duration
Preparation Time: 20 min
Activity Time: 60 min

Setting
Classroom (Groups of 4-5)

Skills
Collecting observations; Identifying patterns; Applying information; Making predictions; Drawing conclusions

Standards

NGSS:
CROSSCUTTING CONCEPT(S):
Patterns; Cause and Effect
SCIENTIFIC & ENGINEERING PRACTICE(S):
Constructing Explanations

Common Core:
WHST.6-8.4: Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

Overview
Students will examine invasive mussel distribution maps to learn how fast invasive mussels can disperse over time, discuss how the mussels move from place to place, and explain how they could impact their local economy and environment.

Objectives
Students will be able to:
- predict where invasive mussels spread from their point of origin in the United States.
- explain how invasive mussel spread naturally.
- identify pathways of introduction and methods of dispersal for invasive mussels.
- track the pathway of invasion from a local point of origin.
- infer how invasive mussels could potentially impact the local economy and environment.

Materials
Warm Up/Activity (Part I)/Wrap Up
- Computer and projector
- Student worksheets #1-2
- One water bottle and two bowls of water (or two sinks)

Activity (Part II)
- One set of materials for each group:
  - One Columbia River Basin map
  - One Flathead Lake Region map
  - One major U.S. watershed map
  - One Montana Reference map
  - Three "100th Meridian Initiative: Intruders Among Us" pamphlets

Advanced Preparation
- Print the student worksheets #1-2 (double-sided).
- Arrange the classroom so that the students can work in groups of 4-5. Place the materials for Part II on each group table.
- Prior to class, pre-load the Mapping AIS Mayhem presentation found on the associated thumb drive or on our website: https://flbs.umt.edu/newflbs/k12teachingmaterial

Funded by the Montana Department of Natural Resources and Conservation and FLBS.

Mapping AIS Mayhem

Background

The speed at which **non-native species** move into new environments outside of their natural range is increasing due to the ways in which people move from one place to the other across our planet. As a result, invasive species are often thought of as a modern problem created by the mass movement of people from place to place. Zebra mussels (*Dreissena polymorpha*) are thought to have been introduced to Lake St Claire, MI in 1986 by the ballast water of cargo ships. Their close relative, the quagga mussel (*Dreissena rostriformis bugensis*), arrived shortly after the zebra mussels in 1989. Since their introduction, zebra and quagga mussels have spread rapidly throughout the United States. The Columbia River Basin is the last major watershed in the country that has not been invaded by non-native mussels.

Montana waterways are constantly under siege from aquatic invasive species. In 2016, invasive mussel larvae or **veligers** were found in Tiber Reservoir on the eastern side of the Continental Divide. As a result, the state of Montana has been working to prevent the spread of the mussels throughout their lakes and rivers. For example, additional inspection stations were created to monitor motorized and non-motorized boat traffic into the state. Prior to the discovery of veligers in Montana, the state inspected ~37,000 boats in 2015. In comparison, the state inspected 109,000 boats in 2018, of which 47,000 were non-motorized vessels. In 2018, the state discovered sixteen boats that were fouled with invasive zebra or quagga mussels.

In addition to boat inspections, the state conducts field surveys to monitor our lakes, rivers, and other water bodies. In 2018, the state collected over 2,100 plankton tows to test for the presence of invasive mussel larvae in our waterways. As a result of their efforts, the state discovered new populations of faucet snails in Lake Frances, curly-leaf pondweed in the Kootenai River, and New Zealand mudsnails in the Missouri River (below Canyon Ferry Reservoir). In 2019, Asian clams were discovered in Lake Elmo State Park in Billings. These new detections show that aquatic invasive species spread easily and are difficult to contain once they enter a water body.

Photo credit: Bjorn S. (CC BY-SA 2.0)

Asiatic clam, Corbicula fluminea, is a small (< 50 mm) invasive mollusk that is native to rivers in southern Asia west to the Mediterranean. It was introduced to the Columbia River in 1938, and since then it has spread throughout the United States.

The Asiatic clam was recently found in Montana for the first time. The Montana Fish, Wildlife and Parks organization is currently conducting surveys in Lake Elmo State Park to determine whether a viable population has established itself in the lake. This clam has a planktonic larval stage or veliger just like zebra and quagga mussels that helps it to disperse easily in water.

Vocabulary

Aquatic invasive species – Aquatic, non-native species that cause economic or environmental harm.
Dispersal – The spread of organisms in an environment.
Intentional transport – The movement of non-native organisms to a new location for a specific purpose.
Invasion barrier – A physical or biological barrier that stops an invasive species from successfully establishing itself in a non-native environment (ex. geographic barrier, reproductive barrier, water chemistry, competition, or predation).
Invasion failure – The failure of an invasive species to successfully establish itself in a non-native environment.
Pathway of introduction – The route an invasive species takes from its source habitat to its location of release.
Transport vector – The way in which a non-native species is moved to a non-native environment.
Unintentional transport – The accidental movement of non-native organisms to a new location.
Watershed – An area of land where all of the water under it or that drains off of it collects in the same place (ex. Columbia River Basin Watershed).

 Funded by the Montana Department of Natural Resources and Conservation, FLBS, and Flathead Lakers.

Part I Procedure

◆ Warm Up (10 minutes)

- Turn on the projector and display the Mapping AIS Mayhem slide show.
- Ask the students why invasive species are more of a problem now than any other time in human history?
- Slide #1: Students interpret the map and guess what the key means. Ask them to share observations they have about the patterns on the map. This map characterizes to what extent invasive species would likely be introduced to different countries due to **global trade** and other similar activities. The areas with "Very High" threat are places with high **human populations**, **greater airport and seaport capacity,** as well as, **significant international travel**, which could be a source of more introductions of invasive species. Ask the students why the Eastern US is more threatened by invasive species. Discuss the ways in which foreign goods are transported to the United States.
- Slide #2: Pass out the student worksheets (#1-2). Ask the students to make a prediction on where they think the zebra and quagga mussels originally came from and how they think they got to the U.S. Students may share their ideas verbally.
- Slide #3: Zebra mussels are native to the Caspian, Black, and Azov Seas in Eastern Europe. All three FRESHWATER bodies of water are connected via natural rivers and the Volga-Don Canal. Approximately 89% of cargo shipped from the Caspian Sea is shipped westward. The cargo is then sent all over the world.
- Slide #4: Quagga mussels are native to the Dnieper River that flows into the Black Sea.
- Slide #5: Share the traits that make these mussels invasive. The zebra and quagga mussel are very similar in size. Both can have stripes with great variation in color. When placed on a table, the triangular zebra shell will sit upright, whereas the rounder quagga shell will fall down. The incurrent siphon brings water into the mussel's body, the food is filtered out, and then the wastewater is released through the excurrent siphon. Each adult mussel can filter up to 1 liter of water per day. **One adult female can release up to 40,000 eggs in one round of reproduction (~1 million eggs/year)**. The eggs and sperm are released from the excurrent siphon into the surrounding water where they combine. The fertilized eggs grow into larval veligers. **These microscopic, planktonic larvae drift with the water currents for up to a month and can be transported great distances**.
- Slide #6: Unlike native mussels found in Montana, the adult zebra and quagga mussels **attach to surfaces with byssal threads**, which allows them to be transported great distances as hitchhikers on man-made objects. They can stay alive outside of water for up to 5 days. The Dneiper River, Black, Caspian, and Azov Seas are all freshwater locations. Ask the students to share how they think the freshwater mussels were transported across the salty ocean and introduced to the freshwater Great Lakes in the United States.
- Slide #7: The mussel larvae can get pumped into the ballast tanks of cargo ships and unintentionally transported to new ports. The ships add ballast water to keep them from tipping over when they have less cargo loaded. Explain to the students that the two sinks in your classroom (or two large bowls) represent the Black Sea and Lake Erie. Explain that the plastic water bottle represents a cargo ship. Walk the empty water bottle (cargo ship) to the "Black Sea" sink/bowl and explain how it would float too high when not loaded with cargo. Fill the "empty ship" with "ballast water" at the port and explain that as the cargo is loaded some water is released at port. Walk the loaded ship across the room to the other sink/bowl and explain as you go that the ship is traveling from the Black Sea to the Mediterranean Sea and eventually out across Atlantic Ocean to the St. Lawrence River (Seaway). The ship will then arrive at the "Lake Erie" sink or bowl and again add ballast water as it unloads the cargo. When the new cargo is loaded at the new port the ballast from the Black Sea is then released into Lake Erie.

◆ The Activity

PART I (25 minutes)

TIP: Quickly clicking back and forth between the slides will allow the students to clearly see the mussel distribution patterns as they appear.

- Slide #8: Explain that you will be flipping through mussel distribution maps that display the new mussel detections starting from when the zebra mussels first arrived in the U.S. Identify the map key, and quickly describe how the cargo ships get to the Great Lakes through the St. Lawrence River or through the Erie Canal located along the Hudson River. Review the names of the Great Lakes, and point out that the lakes are all connected. Ask the students to record the year the zebra mussels first arrived on their worksheet (1986) and to make a prediction and record where they think the mussels will spread to first.
- Slides #9-11: The mussels have now spread to Lakes Michigan and Superior. Notice many of the new mussel detections occurred near major shipping ports. Approximately 4,000 cargo ships pass through the St. Lawrence Seaway annually. Once the invasive mussels entered Lake Erie, it was very easy for them to be transported to other ports, again through the release of ballast water. Students record that the quagga mussels were first detected in 1989.
- Slide #12: Students record that after just four years, the mussels have spread to all five great lakes.
- Slide #13: Five years post introduction: The zebra mussels have spread downstream along the Illinois River and hitchhiked to the Mississippi and Ohio Rivers. The quagga mussels also spread further throughout the Great Lakes.
- Slides #14-17: The zebra mussels have spread downstream along the Mississippi River and hitchhiked to the Arkansas and Tennessee Rivers, and continued to spread throughout the Great Lakes. The quagga mussels have become well established in Lakes Erie and Ontario and they have hitchhiked to the Ohio and Mississippi Rivers.
- Slides #18-19: Ten years post-introduction, the mussels have spread throughout the Eastern U.S. The Great Lakes and major rivers were greatly infested. Students record that they spread quickly by traveling **downstream** from their points of origin and by **hitchhiking** rides on man-made objects.
- Slides #20-24: Fifteen years-post introduction, the zebra mussels are now in northern sections of the Missouri River and the quagga mussels have spread into Lakes Michigan and Huron.
- Slides #25-27: Notice the expansion of quagga mussels in Lake Michigan. The quagga mussels have been reported to displace the zebra mussels when they are growing in the same habitat. The quagga mussels can tolerate colder temperatures and sandier substrates, and, therefore, can grow in deeper water than the zebra mussels.
- Slides #28-29: Twenty years post-introduction, the zebra mussels have fully dispersed throughout the Mississippi River. The western U.S., Maine, and the southeast region are still clear of invasive mussels.
- Slide #30: First, the students record the year the mussels crossed the continental divide. Lake Mead Recreational Area along the Colorado River was one of the first locations in the West to become infested with the invasive quagga mussels. Next, the students brainstorm and record the ways in which the mussels can move and spread to new areas. Write their responses on the board as the students share their ideas. Next, circle the natural methods of dispersal (water currents, birds, etc.) and point out that most of the dispersal vectors are from human activities.
- Slide #31: PEOPLE are the common thread to all of these photos. We spread AIS all over the world by our recreational habits, transportation of goods, and methods of travel. Other vectors of AIS dispersal that are always good to mention are water aircraft, non-motorized vs. motorized watercraft, wading and fishing gear, boats with internal bladders, ballast water from ships, shoes, clothing, nets, and ropes.
- Slide #32: The quagga quickly spread down the Colorado River, to Southern California, and to Colorado. Whereas, the zebra mussels spread to northern California and Utah.
- Slide #33: The farmers and ranchers in Idaho pushed hard for the inspection stations along the Idaho

border to protect their irrigation systems. Notice, there is one inspection station along the eastern border of Montana. These inspection stations were created to inspect all of the WESTBOUND vehicles with boats.

- Slides #34-39: Notice the increase in inspection stations and the fewer instances of new mussel invasions. The quagga mussels have now made it to Nevada so an inspection station was added along the California border to protect Lake Tahoe.
- Slide #40: Thirty years post-introduction, invasive mussels were officially detected in Tiber Reservoir. Initially, the state found mussel larvae in a sample collected at Canyon Ferry Reservoir, but they now think it was contamination from a net used in Tiber Reservoir.
- Slides #41-42: Ask the students to record whether the inspection stations and "Clean, Drain, Dry" campaigns are working in the northwest and what evidence supports their answer.
- Slide #43: Students describe where the mussels have NOT spread to since their introduction. The mussels have spread to every major watershed in the country except the Columbia River Basin. The mussels have NOT spread to New Hampshire, Maine, North Carolina, South Carolina, Florida, Wyoming, Idaho, Oregon, Washington, Hawaii, or Alaska.
- Slide #44: Ask the students to describe potential invasion barriers that could cause a mussel invasion to fail. Potential answers: physical barriers (i.e. mountains, deserts), water chemistry (ex. pH, calcium, salinity), competition, predation, water temperature or only one sex arrives in a lake.

PART II (20 minutes)

- Slide #45: Water moves across the United States by following the path of least resistance. There are 11 major river basins in the United States that direct the flow of water to the Pacific Ocean, Hudson Bay, Atlantic Ocean, and Gulf of Mexico. Rain landing on Triple Divide Peak in Glacier National Park can potentially flow into three different river basins. As a result, AIS that arrive in NW Montana could spread into these three separate basins. The Columbia River Basin is the last major river basin in the United States that does not have invasive mussels. One of the main reasons that zebra and quagga mussels have spread so easily is that their larvae are planktonic, so they can drift and be moved quickly from place to place through water currents, streams, and rivers. Once the adult zebra or quagga mussels get established in an area their larvae can be spread easily in small amounts of water.
- Slide #46: Students work in groups or individually using the maps in the classroom. Explain to the students that the invasive mussels are NOT currently in the Flathead River Basin, but that they could potentially be introduced at anytime. Students select a point of introduction for the invasive mussels on the Flathead Lake Region Map.
- Slide #47: Students track the path of dispersal from the point of introduction.
- Slide #48: Students explain how the aquatic environment could be impacted by a mussel invasion.
- Slide #49: Students think of a personal connection and explain how a mussel invasion could potentially impact someone they know.
- Slide #50: Students select a topic from the provided list. Then, they use details from the Columbia River Basin map to explain potential ways the Columbia River Basin economy could be impacted by a mussel invasion.

◆ Warm Down (5 minutes)

- Slide #51: Students respond to the following prompt on their worksheet: We live near headwaters of the Columbia River Basin. Why should we care about a potential mussel invasion? If there is time, students may share their responses with the class.

Teacher Resources

Assessment Options

Have students:

- **complete the Mapping Activity Part I worksheet** to summarize their understanding of zebra and quagga mussel origins, and the ways in which they can be transported from place to place.
- **complete the Mapping Activity Part II worksheet** to identify potential points of invasive mussel introduction in the Flathead Watershed, potential routes of distribution, and how these mussels could impact the aquatic environment and local economy.

Modifications

- Students may work either in groups or individually as they complete the Mapping Activity Part II.
- To provide additional discussion time, Part I and Part II may be completed on two separate days. If limited in time, Part II may be shortened or skipped altogether.
- Enlarge the students' worksheets as needed.
- Print slides 9-30 and cover the dates. Provide each group of 3-4 students with a set of slides. Challenge the students to organize the maps in chronological order. Why did they choose this order? How do they think mussels move from one location to another?

Extensions

Students can:

- **research** the circumstances in which a Dreissena mussel (or another aquatic invasive species) invasion would fail.
- **design and distribute** Clean, Drain, and Dry "how to guides" for common recreational items used in their community.
- **organize and conduct** a mussel walk event to educate members of their school community (see Mussel Walk Lesson Plan).

Books

Elton, C. S. (2000). *The Ecology of Invasion by Animals and Plants* (new ed.). Chicago, IL: University of Chicago Press.

Lockwood, J. L., Hoopes, M. F., & Marchetti, M. P. (2013). *Invasion Ecology* (2nd ed). West Sussex, UK: John Wiley & Sons, Ltd.

Online Resources

USGS NAS, *Dreissena polymorpha* website:
https://nas.er.usgs.gov/queries/FactSheet.aspx?speciesID=5

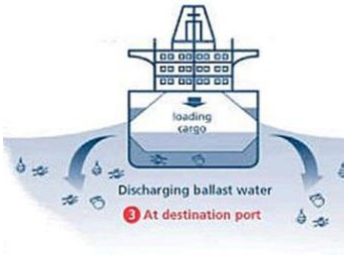
Acknowledgements

Many thanks to Natalie Poremba for designing the mussel distribution, Flathead Lake Region, and Columbia River Basin maps for this lesson. Additional thanks to Ryan Alger for creating the Montana Reference Map.

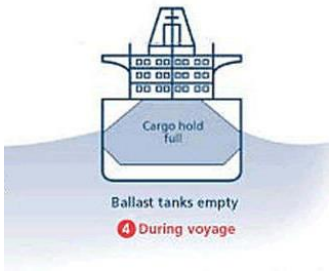
Cargo Ship Ballast:

STEP 1: Water is pumped into the ballast tanks as the cargo is unloaded.

STEP 2: The cargo ship travels to a new port with full ballast tanks.



STEP 3: At a new port the ballast water is released as the new cargo is loaded.



STEP 4: The loaded ship travels to the new port with residual ballast water in the tanks.

Photo credit: International Maritime Organization (2019)

 Name _____

Warm Up

Make a prediction for each question below, share your predications, and then fill in the table below.

	Answer
WHERE are zebra mussels native?	
WHERE are quagga mussels native?	
How did the invasive mussels get to the U.S.?	

Mapping Activity Part I

1. What year were zebra mussels discovered in the U.S.?_____

2. **Make a Prediction**…Where do you think the invasive mussels spread to first?

3. What year were quagga mussels discovered in the U.S.? _____

4. **Where** did they actually spread to initially?

5. The mussels quickly spread by traveling _____ from their points of origin or by _____ a ride on or in a man-made object.

6. What year did the invasive mussels cross the continental divide? _____

7. **30-second brainstorm**…List the ways in which invasive mussels can move and spread to new areas?

8. **How** are the states in the northwest trying to prevent the spread of invasive mussels?

9. Is it working? Why or why not?

10. **List** the states the invasive mussels have **NOT** spread to since their initial introduction.

11. What do you think are some **invasion barriers** that could cause a mussel invasion to fail?

Mapping Activity Part II

Student Worksheet (2 of 2)

Examine the provided maps with your group members and then answer the questions using complete sentences.

Flathead Watershed Map:

Imagine the invasive mussels have made it to the Flathead River Basin in Montana.

1. Select a point of introduction on the Flathead Watershed map: _____
2. Describe **where the mussels would disperse/spread** from that location below.

3. Explain (using SPECIFIC details from the map) how the **aquatic environment** of the Flathead Watershed could be impacted by a mussel invasion.

4. Think of a **personal connection**…how could a zebra or quagga mussel invasion impact someone you know or a particular profession in the region?

Columbia River Basin Map:

How could the Columbia River Basin be economically impacted by a mussel invasion?

5. Select a topic below. Use SPECIFIC details from the map to explain how these Columbia River Basin businesses could be impacted by a mussel invasion.
   - ☐ Hydroelectric Dams
   - ☐ Farming/Irrigation
   - ☐ Real Estate
   - ☐ Restaurants
   - ☐ Tourism
   - ☐ Recreation (ex. fishing, rafting, swimming, sailing, boating, camping, etc.)

Wrap Up

6. We live near headwaters of the Columbia River Basin. Why should we care about a potential mussel invasion?