TIEE
Teaching Issues and Experiments in Ecology - Volume 1, January 2004

ISSUES – FIGURE SET

What Are the Impacts of Introduced Species?

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Brown tree snake, *Boiga irregularis*
photo © G. H. Rodda, USGS
{biology.usgs.gov/s+t/
imagefiles/x181w02.htm}

Figure Set 1: Zebra Mussel Invasion

Purpose: To help students connect the biological and life history characteristics of zebra mussels to their invasion success.
Teaching Approach: "Think-Pair-Share"
Cognitive Skills: (see Bloom's Taxonomy) — knowledge, interpretation
Student Assessment: essay quiz

BACKGROUND

The zebra mussel (*Dreissena polymorpha*), native to southern Russia, was introduced to the Great Lakes in 1985 or 1986 via ballast water from foreign ships. Since then it has spread quickly and caused dramatic economic and ecological effects. Zebra mussels now exist in many aquatic systems in the eastern US and are expected to invade freshwaters throughout the nation in about 20 years. The mussel can reach densities of up to 700,000 individuals/m^2. It outcompetes other filter feeders for food, smothers clams, native mussels and snails, and clogs water intake and exit pipes for facilities such as electric generating plants. Pimentel et al. (2000) estimate annual damage for U.S. utilities at about $100 million.

Lack of predators and parasites are partly responsible for the success of the zebra mussel in the U.S. Availability of space is another reason. Hard substrates such as pipes appear to be an open niche for the mollusk; several publications include striking photographs of cars and barrels completely covered with zebra mussels. Its physiological plasticity and human transport in ballast and other water also contribute to the mussel's spread.

The biology of the zebra mussel predisposes *D. polymorpha* to be a successful invader. For instance, the free-swimming veliger larva can disperse widely. Females are also extremely fecund. This exercise will help students understand the several life history and ecological characteristics of the mussel that contribute to its ability to invade freshwaters so successfully.

STUDENT INSTRUCTIONS

First read the information below on your own. Then discuss your answers with your neighbors and ask them to help you with any questions you may have. Be prepared to share your answers and questions with the whole class.

One of the most dramatic examples of a successful invasion by an introduced species is the zebra mussel, *Dreissena polymorpha*. This native to southern Russia was introduced to the Great Lakes in 1985 or 1986 via ballast water from foreign ships. Since then, it has spread rapidly throughout the Great Lakes, into the Hudson River in NY state, and into many other freshwater habitats in the eastern U.S. (Figure 1a).

Note that ships travel from the open ocean into the Great Lakes via the St. Lawrence River in Quebec, Canada (Figure 1a). To ride low in the open ocean big ships take in water (called ballast water) after they unload heavy cargo. After taking in ballast water in large rivers in southern Russia, the vessels traveled across the Atlantic Ocean and into the Great Lakes, where the "Russian" ballast water was then discharged when the ships took on more cargo. Any organism that survived this trip became potential Great Lake "invaders".

It is predicted to invade most lakes and rivers in the nation in about 20 years. Zebra mussels grow in incredible densities of up to 700,000 individuals/m^2 (try to picture that!). Any hard surface in water like a car or a shopping cart will be completely covered in mussels in a few months. The ability of these mussels to cake onto surfaces has created havoc for utilities in the Great Lakes and elsewhere because pipes that take in and discharge water become quickly clogged. Estimates of the cost to remove mussels (by chlorine and other chemicals and hot water) are as high as $100 million per year. Some organisms are very successful at invading and growing in places in the world where they are not native. Many others are not. The zebra mussel's biology and ecology predisposes it to be a successful introduced species.

Use the list of characteristics below to explain *D. polymorpha*'s ability to flourish in the U.S.

Characteristics of the zebra mussel:

- Lifespan is typically three to five years,
- Shells are usually 25-35 mm in length,
- They reach sexually maturity in the second year, sometimes in the first year,
- Sexes are separate, gametes released into water for external fertilization,
- Individual females can release more than one million eggs in a spawning event; eggs are released 2-5 times a year,
- Fertilization requires water of at least 12 degrees C; eggs can be fertilized 2.5-5 hours after release and sperm last up to 22 hours,
- The free-swimming larvae, called veligers, are spread by currents; a later stage settles onto surfaces and firmly attaches itself to a surface with byssal threads which it excretes,
- Adults spread via boats they are attached to,
- The mussel can live in fresh and brackish water; it does not tolerate low pH or low oxygen,
- Adults grow in huge concentrations on top of one another,
- Zebra mussels are filter feeders and they can filter very large volumes of water often the whole volume of a lake or reservoir in a few months,
- U.S. lakes and rivers with high densities of zebra mussels become very clear and the chlorophyll concentration in the water drops dramatically.

FIGURES

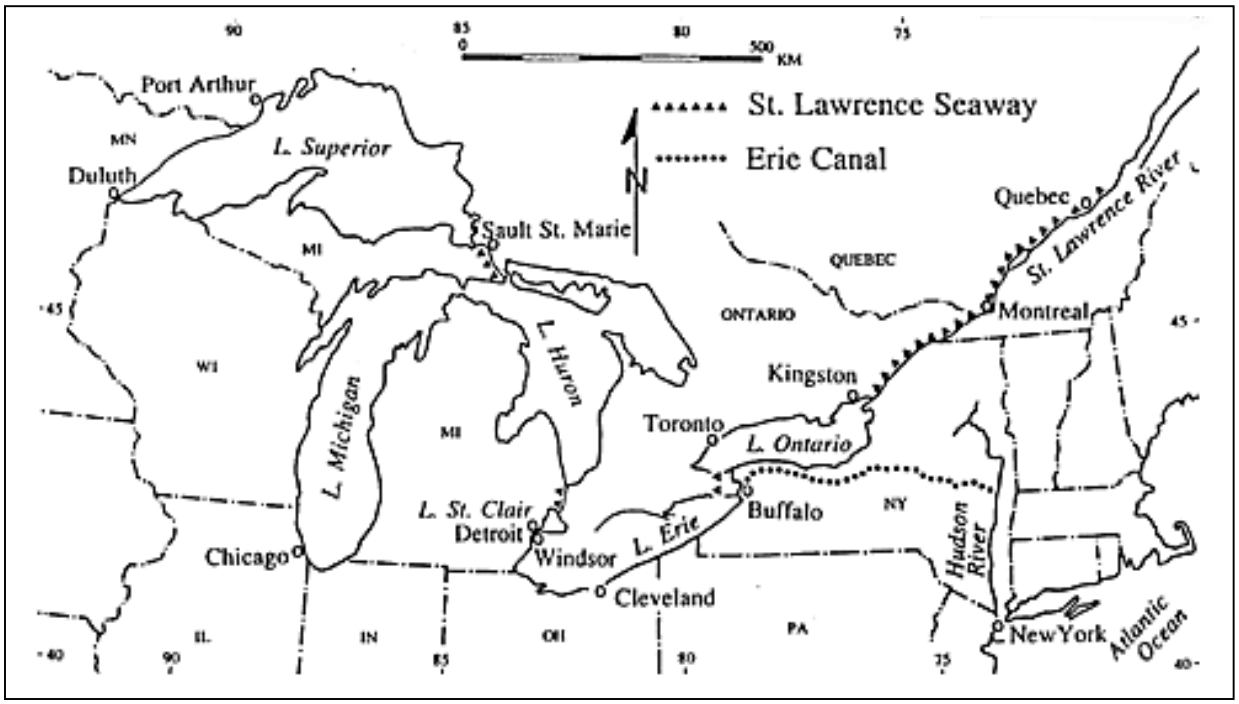

Figure 1A. A map of the Great Lakes including the St. Lawrence Seaway and the Erie Canal (from Mills, E. L., J. H. Leach, J. T. Carlton, and C. I. Secor. 1994. Exotic species and the integrity of the Great Lakes. BioScience 44: 666-676).

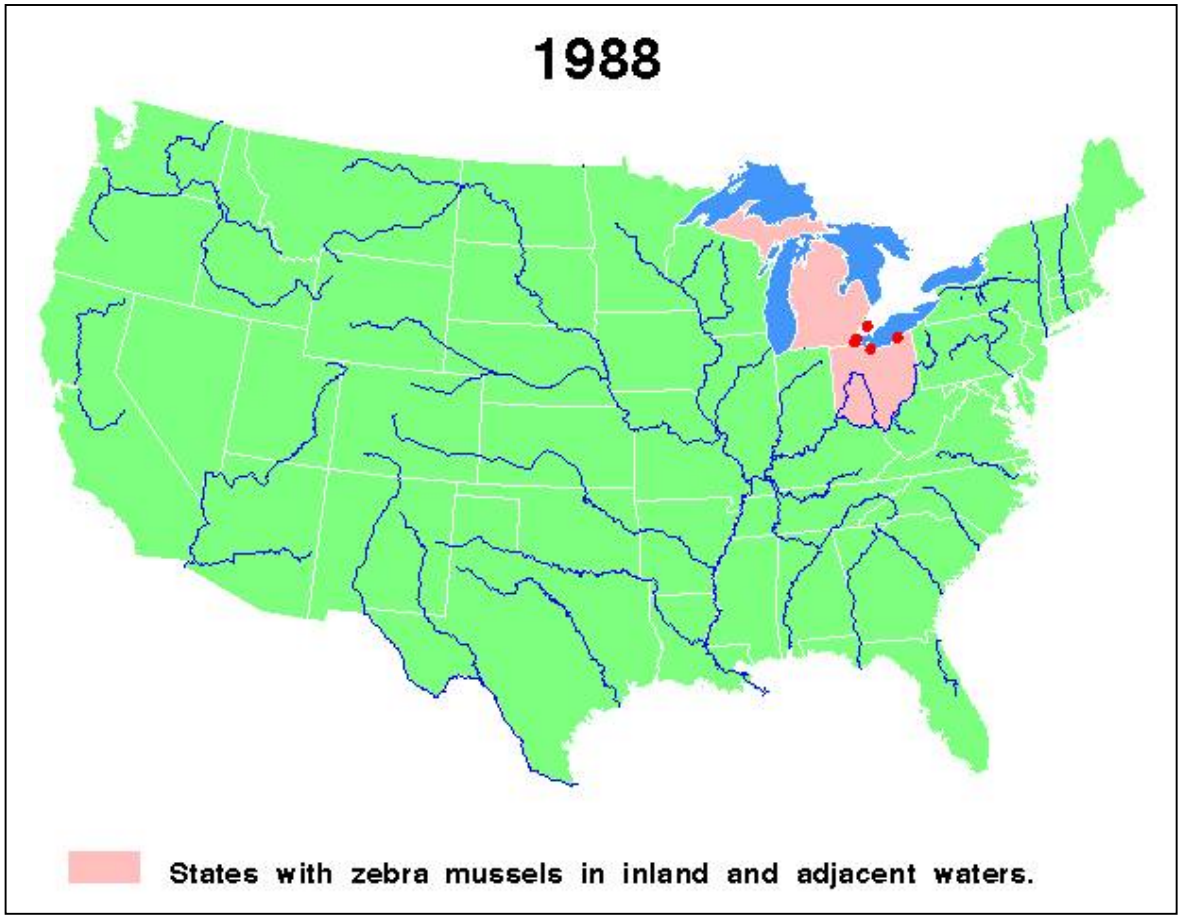

Figure 1B. A map showing the distribution of zebra mussels in the Great Lakes region in 1988 (USGS, 2003. Zebra Mussel Information: U.S. Distribution Maps, http://nas.er.usgs.gov/zebra.mussel/).

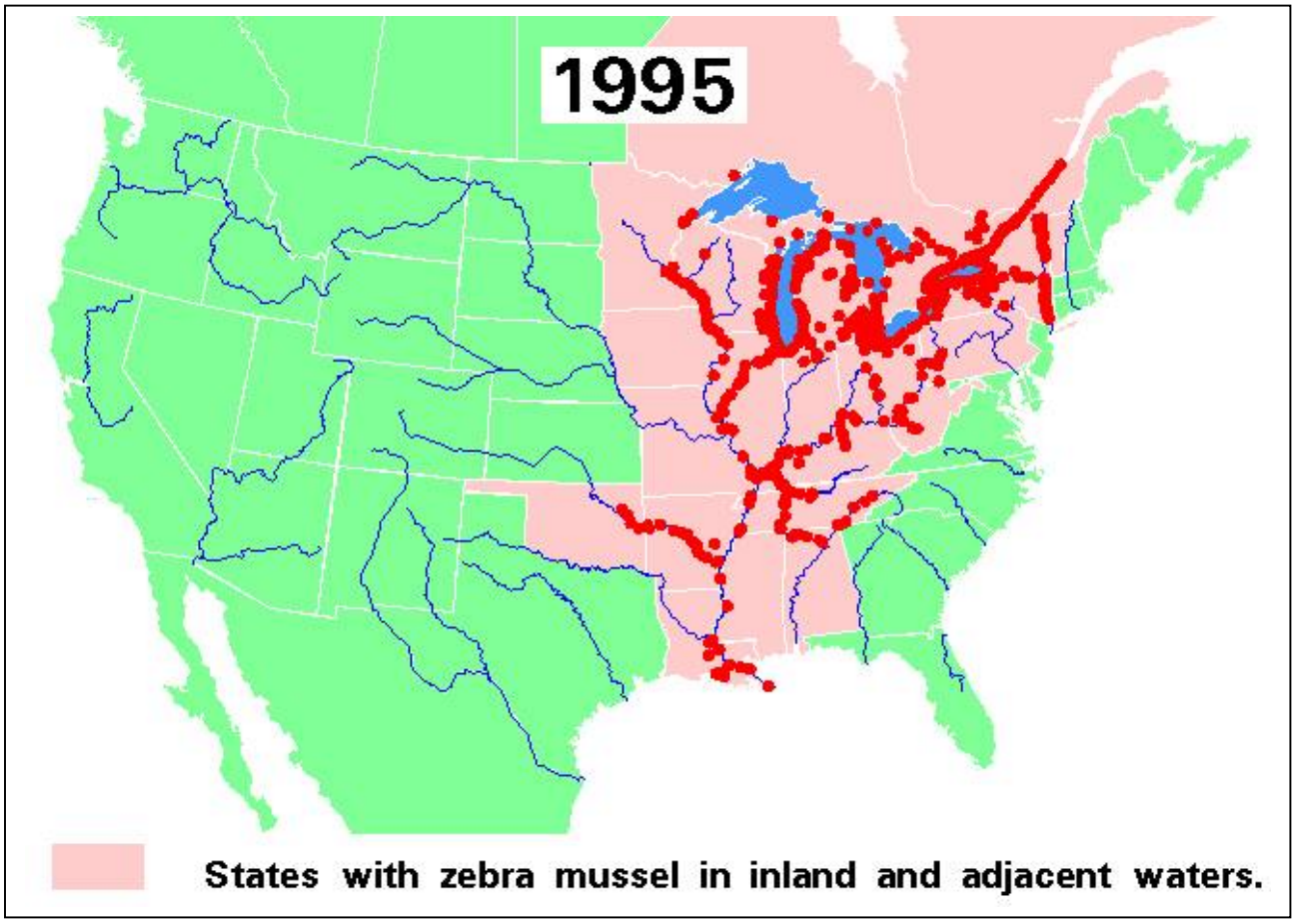

Figure 1C. A map showing the distribution of zebra mussels in the Great Lakes region in 1995 (USGS, 2003. Zebra Mussel Information: U.S. Distribution Maps, http://nas.er.usgs.gov/zebra.mussel/).

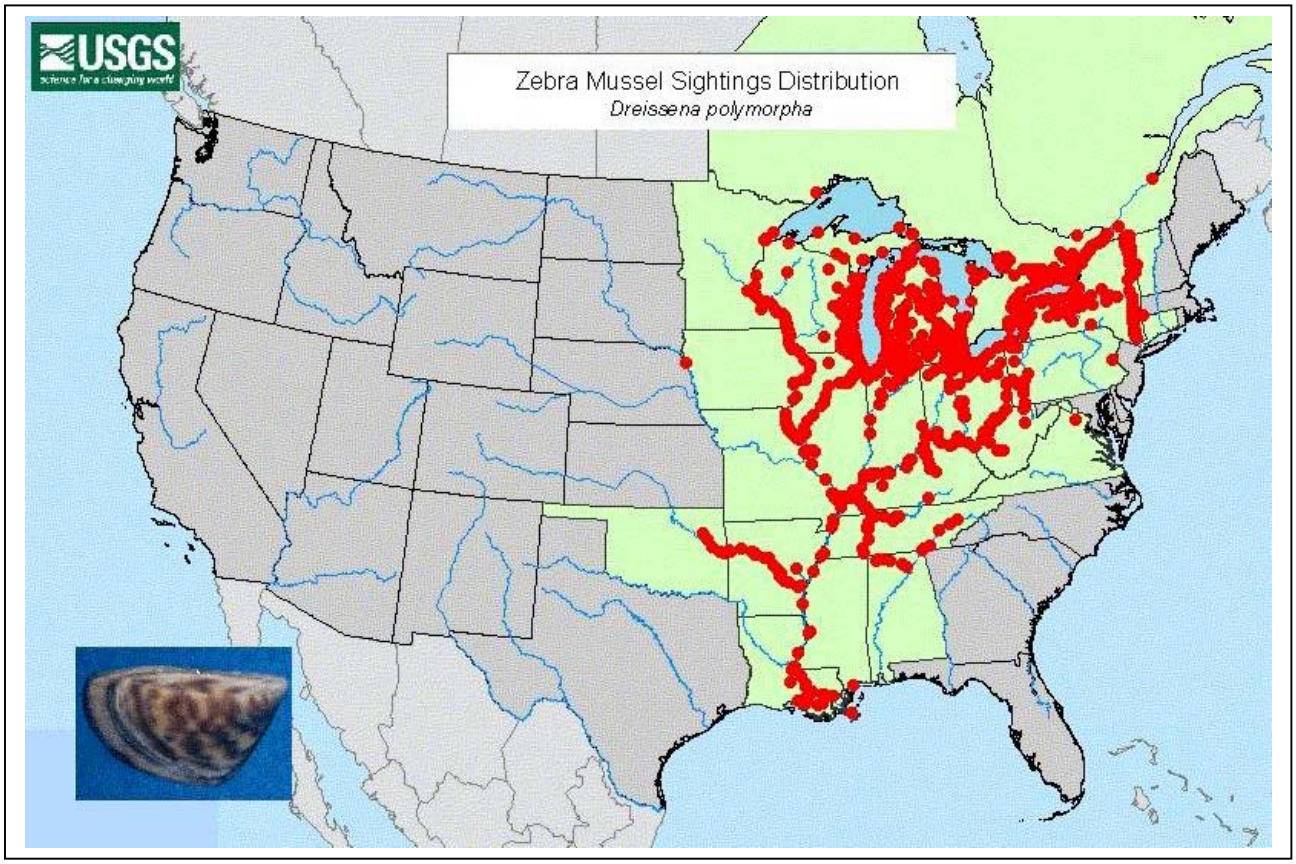

Figure 1D. A map showing the distribution of zebra mussels in the Great Lakes region in 2002 (USGS, 2003. Zebra Mussel Information: U.S. Distribution Maps, http://nas.er.usgs.gov/zebra.mussel/).

FACULTY NOTES

The timing of both the individual (read alone) and paired work (discuss together) depends on the sophistication of your students. Tell them how long they have for each and signal the times with a bell, switching off and on the lights, etc. if you have a large class. Make sure the students understand what ballast water is and how fresh water from Russia could have ended up in the Great Lakes.

Important characteristics include: a relatively long lifespan for an invertebrate, fairly early sexual maturity, huge release of eggs, spawning events several times a year, eggs and sperm viable for several or more hours, tremendous dispersal by free swimming veliger, firm attachment onto surfaces with byssal threads, dispersal of all life stages, tolerance of some salinity, ability to filter plankton from large volumes of water. You may need to make the point that these characteristics are not inherently "bad" (e.g. many aquatic organisms colonize submerged hard surfaces).

Write the qualities listed by your students on an overhead or the board and ask them to explain how each one contributes to the success of this invader. Help them imagine some of the fascinating traits of this mussel - what nearly a million mussels/m^2 looks like or a million eggs, veligers carried long distances by currents, adults moving around via the hulls of ships and small boats, the volume of a lake moving through the mussels as they filter feed. You can use photos from books and the web to illustrate some of these points.

Discussion questions:

- Introduced species in general are successful at invading some habitats more than others. What types of habitats would you predict these to be?
- After zebra mussels were introduced to the Hudson River in the early 1990's the water became much clearer and phytoplankton concentrations decreased about fivefold. Why did this happen and what might the consequences be?
- Marine organisms are transported all over the world via ballast water in ships, and this is an important dispersal mechanism for species introductions to estuaries. Imagine that you were going to study this phenomenon. How might you go about collecting samples and what factors in particular would you look at that determine success of potential invaders (e.g. length of a voyage)?
- Zebra mussels are not pest species in their native waters in Russia. Why are they such a nuisance elsewhere but not in Russia?
- Do scientists "know" that these sets of life history characteristics are what lead to the success of zebra mussels as an invasive species? What information would help you feel more confident about that assertion (comparison with non-invasive species)?

Student Assessment: Essay Quiz

Select 3 life history traits of the zebra mussel and explain why these characteristics contribute to its success as an introduced species. Write paragraphs (can be more than one per trait) of 100-200 words for each characteristic.

Evaluating an Issue: How do you know whether it is working?

On-going (also called formative) evaluation of the approaches your are using is critical to the success of student-active teaching. Why try out new ideas if you don't know whether or not they are working? This is a brief overview of formative evaluation. For more information, go to the Formative Evaluation essay in the Teaching Section.

Course Goals:

Formative evaluation only works if you have clearly described your course goals - because the purpose of the evaluation is to assess whether a particular technique is helping students reach these goals. For instance, most of us have "learn important ecological concepts and information" as a course goal. If I reviewed the nitrogen cycle in a class, for evaluation I might ask students to sketch out a nitrogen cycle for a particular habitat or system. Each student could work alone in class. Alternatively, I might ask students to work in groups of 3 and give each group a different situation (e.g. a pond receiving nitrate from septic systems, an organic agricultural field, an agricultural field receiving synthetic fertilizer). The students could draw their flows on a large sheet of paper (or an overhead transparency) and present this to the rest of the class.

The Minute Paper:

Minute papers are very useful evaluative tools. If done well they give you good feedback quickly. Minute papers are done at the end of a class. The students are asked to respond anonymously to a short question that you ask. They take a minute or so to write their response in a 3x5 card or a piece of paper. You collect these and learn from common themes. In the next class it is important that you refer to one or two of these points so that students recognize that their input matters to you. The UW - FLAG site (www.wcer.wisc.edu/nise/cl1/flag/) gives a good deal of information about using minute papers including their limitations, how to phrase your question, step-by-step instructions, modifications, and the theory and research behind their use.

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