Invasion of the Zebra Mussels

Bethany Kempster, Teacher, Royal Ontario Museum

ACTIVITY DESCRIPTION:

The harm caused by invasive species is now the second leading threat to global biodiversity. With twenty percent of the Earth's freshwater, one of the world's longest coastlines, and extensive global shipping, it is sadly no surprise that Canada gains approximately fifteen new invasive species every decade.

This lesson plan contains four activities for Grade 12 Biology students. Students examine a real data set of zebra mussel densities collected from the Rideau River Canal System, graph and analyze the data, and consider the importance of proper sampling techniques. Students then calculate the hypothetical population sizes of zebra mussels in Lake Erie, how long it would take zebra mussels to filter all of the water in Lake Ontario, and calculate the hypothetical population zebra mussels could reach in just five years. Students finish by researching possible zebra mussel control methods and vote on which methods are most and least effective.

MATERIALS NEEDED:

- Graphing software
- Data set (attached)

TIME NEEDED:

- Activities 1, 2, and 3: Could be completed in one period
- Activity 4: Could be completed as independent work, plus one period for debate and discussion

CURRICULUM CONNECTIONS:

Grade 12, Biology, University Preparation: Population Dynamics

- F2.2 use conceptual and mathematical population growth models to calculate the growth of populations of various species in an ecosystem
- F3.3 explain factors such as carrying capacity, fecundity, density, and predation that cause fluctuation in populations, and analyse the fluctuation in the population of a species of plant, wild animal, or microorganism
- F3.5 explain how a change in one population in an aquatic or terrestrial ecosystem can affect the entire hierarchy of living things in that system

BACKGROUND:

The zebra mussel (*Dreissena polymorpha*) is a small freshwater mussel native to southern Russia and Ukraine. The mussels have been introduced to many countries around the world including Canada. Zebra mussels were first discovered in two locations in the Great Lakes Basin in North America: Lake Erie in 1986, and Lake St Clair in 1988. Although the adults are sessile, they are capable of moving on their own downstream as drifting larva, and as well as overland from one body of water to the next attached to boats. In the three decades following their introduction, they have spread across the eastern half of North America, and in Canada are established in Ontario, Quebec, and Manitoba.

Because of their high fecundity, proficient filter feeding, and ability to settle on almost any solid substrate, they outcompete native mussels, reduce available phytoplankton and zooplankton, and modify the cycling of nutrients. In North America, the damage and control costs of zebra mussels have been estimated to be one billion dollars annually. Zebra mussels are the second most costly invasive species for Ontario municipalities. In 2018 Ontario municipalities were estimated to spend a collective $4.9 million dollars controlling zebra mussels. There are currently no safe, effective, and cost-efficient control methods. Preventing the spread of zebra mussels has become the primary focus of many jurisdictions that do not currently have zebra mussels including across the Canadian prairie region and the Midwestern United States.

TEACHING PROCESS AND CLASS ACTIVITIES:

ACTIVITY 1. GRAPHING AND ANALYZING THE DATA

- Hand out the attached data set on zebra mussel densities. The data was collected from sites along the Rideau River Canal System in Eastern Ontario (Martel, A.L, and Madill J.B. 2018). The first zebra mussels were spotted in the fall of 1990 on a large steel boat that had been in Lakes Erie and Ontario that summer. By 1993, zebra mussel populations were established in the lower half of the river. By 1995, densities in some areas had reached over 300 000 mussels/m^2.
- Enter the data into a graphing program such as Microsoft Excel. Using your best judgement, create a graph showing the number of zebra mussels in the Rideau River Canal System over the given time frame.
- **For discussion**: What trends do you see? What are your interpretations from this data? Is this the best way to display the data? How did your graph differ from the graphs generated by other students?
- The authors of the original paper used a logarithmic scale to display the data. Try this with the data set.
- **For discussion**: How did this change the display of the data? Why did the authors choose this display method?
- **For discussion**: If you were in charge of sampling a river bed inhabited by millions of zebra mussels, what sampling techniques would you use? What could account for the high variability in the size of the zebra mussel populations from one site to the next? [In rivers, zebra mussels are impacted by unidirectional flow and minimal suitable substrates. The constant flow of water downstream makes it difficult for zebra mussel densities to grow as their larva are swept downstream.]
- **For discussion**: Sampling was not carried out every year at every site. Can we guess

what is happening to the zebra mussel populations in the missing years? What could account for the high variability in the size of the zebra mussel populations from one year to the next at the same site? [The ability of zebra mussels to survive and reproduce depends on environmental factors including water temperature, turbidity, flow rates, suitable substrate, salinity, pH, oxygen, and food source.]

ACTIVITY 2. THEORETICAL GREAT LAKES DENSITIES

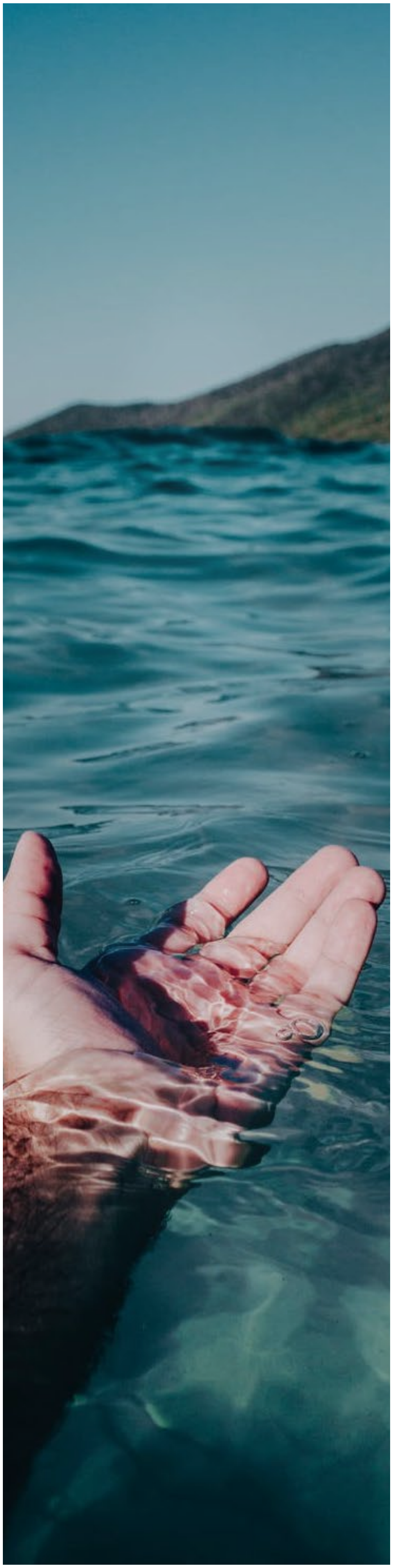
- The surface area of Lake Erie is approximately 26 000 km^2. Let's assume that the bottom of the lake has the same surface area. Calculate how many zebra mussels would be in Lake Erie at the following densities: 2 mussels/m^2; 50 mussels/m^2; 75 000 mussels/m^2; 300 000 mussels/m^2; and a maximum density of 700 000 mussels/m^2.
- **For discussion**: Are these densities sustainable? Would you expect the densities to be even across the entire lake bottom? [Typically, the densest populations are found between 2 and 12 metres in depth. Specimens, however, have been recorded as deep as 60 metres – and Lake Erie is only 64 metres deep!]
- Each zebra mussel can filter one litre of water a day. Assume an average density of 3000 mussels/m^2 in Lake Ontario. If the surface area of Lake Ontario is approximately 19 000 km^2 and the volume of water in Lake Ontario is 1 640 trillion litres, how long will it take the zebra mussels to completely filter all the water in Lake Ontario?
- **For discussion**: Zebra mussels remove almost any type of phytoplankton and zooplankton. What are the ramifications on the rest of the Great Lakes ecosystem if this huge volume of water is filtered every day? Why has plant growth increased dramatically where zebra mussels flourish?

ACTIVITY 3. A PURELY MATHEMATICAL INVASION OF THE GREAT LAKES

- Female zebra mussels lay between 30 000 and 1 000 000 eggs per year. Assume that only 1% of juveniles survive to breed in the next year and half of those are female. The typical lifespan is 4-5 years. Sexual maturity is reached in two months.
- Create a graph showing how the population of zebra mussels would grow over five years starting with a single breeding pair. Assume the number of young per year is 500 000 and only one batch of eggs is laid per year.
- Try the scenario again assuming that two batches of eggs are laid per year (and that the young from the first batch can reproduce later that year). The other factors remain the same.
- **For discussion**: What type of growth is the graph displaying? Is this realistic? What factors would limit and eventually stop unchecked population growth? Has this happened in the Great Lakes?

ACTIVITY 4: ZEBRA MUSSEL REMOVAL

- There are currently no safe, effective, and cost-efficient control methods to remove zebra mussels once they have become established. Working alone or in small groups, students select one potential control method and write a research report highlighting the positives and negatives of the control method.
- Students report to the class on their control methods. After hearing all the options, the class will debate and decide on which method they consider the most and least effective.



ASSESSMENT

These activities were designed to give students a chance to analyze real data relating to population dynamics. Activity four could be assessed and would fall under the communication assessment.

REFERENCES

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Page 1 Zebra Mussel Photo: Amy Benson, U.S. Geological Survey, Bugwood.org

Page 2 Zebra Mussel Photo: Randy Westbrooks, Invasive Plant Control, Inc., Bugwood.org

Page 3 Zebra Mussel Photo: Amy Benson, U.S. Geological Survey, Bugwood.org

For more resources and activities about Ontario's biodiversity, please visit the Biodiversity Education and Awareness website at https://biodiversityeducation.ca/.

DATA SET

Location/ Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2015
Smith Falls	0.01	0.02	2			3		4	159	97	7	64	244	36	66	61	64	97	123
Old Slys	0	0	0.47	0.67	0.13	27	24	2	124	51	2	5	42	2	3	0	9	34	24
Edmonds	0	0	0.8	4	8	15	54	13	79	90	5	4	76	9	10	9	4	31	9
Merrickville	0	0.02	2	2	2	8	21	4	41	35	383	43	864	60	572	83	11	288	1 814
Upper Nicholsons	0	0	6	13	9	8	166	9	226	108	413	125	6 205	59	778	66	19	564	1 791
Burritts Rapids	0.01	0	28	19	51	95	95	264	1 046	711	22 308	570	6 202	1 381	169	420	156	851	2 960
Kars	0.9	486	44 702	47 310	139 829	74 993	58 157	62 564	64 027	105 253					76 160				24 800
Long Island	0.07	23 000	383 100	305 150	442 400	164 427	71 800	229 493	42 840	254 145					53 013				2 969
Black Rapids	0.3	156	168 914	15 886	70 278	37 500	59 050	3 800	58 273	88 587					46 333				28 160
Mooney's Bay	2	1 244	296 374	20 314	93 345	134 630	126 860	745	109 013	157 440					156 510				25 409
Hogs Back	4	1 952	460 960	125 090	217 080	164 600	412 800	12 257	279 447	396 827					235 227				9 600
Hartwells	23	3 518	159 120	64 500	213 909	168 420	187 440	78 080	268 640	583 067					148 160				52 400
Ottawa	0.02	7	141	3 234	6 370	915	9 675	990	63 510	4 621					34 160				6 764

Zebra mussel (*Dreissena polymorpha*) mean densities (measured in mussels/m^2) from 13 sites along the Rideau River and Rideau Canal from 1993 to 2015. Data from Martel and Madill 2018.