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Research Paper Review #1

Article:

Huang, Q., Wang, H., Ricciardi, A. Temperature- and Turbidity-Dependent Competitive Interactions Between Invasive Freshwater Mussels. Bull Math Biol (2016) 78: 353. DOI:10.1007/s11538-016-0146-4. http://link.springer.com/article/10.1007/s11538-016-0146-4

Abstract: We develop a staged-structured population model that describes the competitive dynamics of two functionally similar, congeneric invasive species: zebra mussels and quagga mussels. The model assumes that the population survival rates are functions of temperature and turbidity, and that the two species compete for food. The stability analysis of the model yields conditions on net reproductive rates and intrinsic growth rates that lead to competitive exclusion. The model predicts quagga mussel dominance leading to potential exclusion of zebra mussels at mean water temperatures below 20˚C and over a broad range of turbidities, and a much narrower set of conditions that favor zebra mussel dominance and potential exclusion of quagga mussels at temperatures above 20˚C and turbidities below 35 NTU. We then construct a two-patch dispersal model to examine how the dispersal rates and the environmental factors affect competitive exclusion and coexistence.

Review:

1. What is the problem being discussed?

The quagga mussel and the zebra mussel are two kinds of freshwater mussels with similar ecologies, life cycles and morphologies that have invaded waters in places such as North America, Europe, Canada and Russia. It has been observed that patterns of dominance and competitive exclusion between the two species vary by location and over time, possibly being affected by environmental factors. In this study, the authors' analyze two of the environmental elements that might cause different competitive outcomes of the two mussels: temperature and turbidity. The author's study fertility, survival and food consumption rates for adult and juvenile quagga and zebra mussels in order to develop a competition population model that includes the influence of temperature (in ˚C) and turbidity (in NTU) in the dominance of one mussel over the other. They also analyze the interaction of the two mussels in different patches within the same ecosystem based on dispersal rates.

2. What has been done before by this and/or other authors?

The competition model for quagga and zebra mussels developed in this study follows the "competitive exclusion principle", which suggests that two similar species cannot coexist in the same environment when competing for the same resources. Cushing developed this principle in 2004 and it follows a single-patch model. Authors such as Dermott and Munawar in 1993 and Karatayev in 2014, have suggested that both species function in the same ecosystem but in different patches that exhibit the same environmental conditions. This led these authors to develop a two-patch dispersal model for the dynamics of the two mussels. The authors also used data from previous studies to estimate multiple variables in their model. For example, in 2010 Mackie and Claudi proposed optimal temperature and turbidity levels for quagga and zebra mussels; Baldwin in 2002 conducted research on the growth and feeding biology of both species and determined the assimilation efficiency of quagga mussels is much higher than zebra mussels for feeding; Thorp in 1998 estimated the maximum survival rates of quagga and zebra mussels; Stoeckmann in 2003 compared the reproduction in sympatric populations of zebra and quagga mussels.

3. What do these authors do that is new? Summarize the main results.

These authors build a dreissenid mussel competition model with survival rates based on turbidity and temperature using data from previous studies to determine multiple variables. This single-patch model concludes that quagga and zebra mussels cannot coexist in the same ecosystem. They further extend the single-patch model to a two-patch dispersal model of quagga and zebra mussels. This model assumes that the two species compete for food within the patch they live but populations in different patches do not compete. They then investigate the question of how dispersal rates affect the competitive outcomes of the mussels. They conclude that this model suggests that both competitive exclusion and coexistence can occur based on different dispersal rates.

4. What tools do they use to address the problem, e.g., field studies, lab experiments, data analysis, mathematical model development, computer simulation, mathematical analysis? How do they use these tools?
In this study, the authors developed a single-patch, stage-structured competition model based on a shared life cycle of zebra and quagga mussels. After they built the model they used mathematical analysis to determine the equilibriums of the system and then analyze their stability using the jacobian matrix. Additionally, they used model parameterization to connect previously gathered experimental data to the model and determine variable values. They used computer simulation (with Matlab) to illustrate the impacts of temperature and turbidity on competitive exclusion. Computer simulation was also used to show population interaction based on different dispersal rates for the two-patch system.

5. Select one important figure and summarize what it describes and what is its significance.

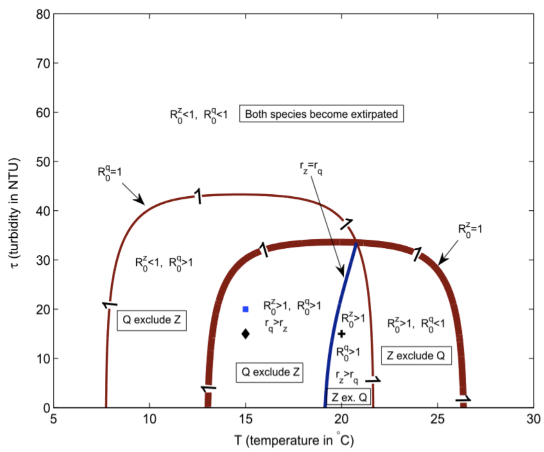

Figure 2 depicts the results of competitive exclusion using the single-patch competition model for different temperatures and turbidities. The lowercase r's (rq and rz) represent the growth rates of quagga and zebra mussels and the capital R's (Rq and Rz) represent the net reproductive rates of quagga and zebra mussels. The figure shows five different environmental "niches", which are divided by three lines: when Rq=1, when Rz=1 and when rq=rz. The top niche suggests both species will become extinct if temperatures and turbidity get higher than a certain level because net reproductive rates will fall below one. The remaining four niches suggest one species with exclude the other based on certain temperatures and turbidities. The figure predicts the quagga mussel will exclude the zebra mussel at mean water temperatures less than 20˚C and over an extensive range of turbidity levels. Further, it predicts zebra mussel dominance at mean water temperatures greater than 20˚C and turbidity levels less than 35 NTU. It indicates quagga mussels have a wider range of temperature and turbidity values for which they will exclude the zebra mussel compared to the zebra mussel excluding the quagga mussel.

6. What are the open questions and/or what is their plan for the future?
For the two-patch model there was eight separate equations, which made theoretical analysis complicated so the authors left it for future development. They also said they plan to extend the one-patch competition model to a benthic-drift model (Huang) by including larval dispersal in drift and juvenile and adult competition on the benthos. They suggest they could use net reproductive rate theory by Krkosek and Lewis (2010) to further understand growth, dispersal, environmental conditions and river flow in determining invasion success by zebra and quagga mussels in upstream waters.