The Effect of Dispersal Heterogeneity in Bioinvasions

Abstract

Population spread of an invasive species is a complex ecological phenomenon involving the interplay between a number of processes, including demography and dispersal of organisms, and variability in these processes. In this dissertation, we provide a framework to study these processes by integrating recent advances in modelling and estimating dispersal into an integro-difference equation. We specifically study the invasive green crab, Carcinus maenas, that has maintained a relatively consistent rate of advance for over 100 years covering a wide range of temperate latitudes and local hydrological environments along the Atlantic coast of North America. Although we use the green crab invasion as a case study, our models can be modified for any species of interest.

A review of the existing work on the theory of spatial models is given in Chapter 1. For convenience, some basic mathematical concepts and results on spatial models are also given in this Chapter.

In Chapter 2, we develop an age-structured integro-difference equation model to investigate the green crab's spreading speed and the relationship between demography and dispersal. The model couples a matrix for population growth and a dispersal kernel for spread of individuals within a season. The choice of a Normal or Laplace distribution for the dispersal kernel has only a minimal effect on the spreading speed. Our modeling exercise illustrates that there are many realistic combinations of vital rates (fecundity and survival) and dispersal rates that give rise to a given spreading speed. Further, by sensitivity analysis we enhance understanding of invasion biology, specifically the relative importance of demography versus dispersal distance for marine species with a pelagic larval stage. We also provide insights on and rank possible management strategies.

In Chapter 3, we focus on the effect of year-to-year variation in larval dispersal on the invasion spread rate. We develop an age-structured integro-difference equation model in which the kernel describing larval dispersal, the main dispersive stage, is mechanistically modeled. This kernel is parameterized using a 3-dimensional hydrodynamic model of the Gulf of St Lawrence for further studying of the green crab invasion. Results indicated that when dispersal parameters vary with time, knowledge of the time-averaged dispersal process is insufficient for determining the upstream spread rate of the population. Rather upstream spread is possible over a number of years when incorporating the yearly variation, even when there are only a few “good years” featured by some upstream dispersal among many “bad years” featured by only downstream dispersal. Accounting for annual variations in dispersal in population models is important to enhance understanding of spatial dynamics and population spread rates.

In Chapter 4, the procedure of estimating larval dispersal kernel used in our models and detail of statistical analysis are provided. We conclude that the role of year-to-year heterogeneity in changing the features of organisms' dispersal is very location dependent. Lastly, some concluding remarks and some possible future work on integro-difference equation models are presented in Chapter 5.
Ph.D. Candidate
Ali Gharouni
Graduate Academic Unit
Mathematics and Statistics

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Room 202

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Examining Board:
Dr. Lin Wang (Math & Stats)  Supervisor
Dr. James Watmough (Math & Stats)
Dr. Jeffrey Picka (Math & Stats)
Dr. Myriam Barbeau (Biology)
Dr. Stephen Heard (Biology)  Chairperson

External Examiner:
Dr. Michael Neubert
Dept. of Biology
Woods Hole Oceanographic Institution

The Oral Examination will be chaired by:
Dr. Heather Sears, Assistant Dean of Graduate Studies

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BIOGRAPHY

Universities attended (with dates & degrees obtained):
2009-2016  PhD Mathematical Biology candidate, University of New Brunswick
2005-2008  MSc Geometry, Isfahan University of Technology, Isfahan, Iran
2000-2005  BSc Applied Mathematics, Shiraz University, Shiraz Iran

Publications:


5. A. Gharouni*, L. Wang, Dynamics of intraguild predator-prey with specialist prey, (to be submitted)

Conference Presentations:


Ali Gharouni*, Myriam Barbeau, Andrea Locke, Lin Wang, James Watmough, An Integrodifferential Model for Biological Invasion of European Green Crab (*Carcinus maenus*). Special Session on Mathematical Models in Biology and Physiology I Fall Southeastern Sectional Meeting University of Louisville, Louisville, KY, October 5-6, 2013 Meeting #1092.

Several Other Conference Presentations