Project proposal 1: Trophic structure and diversity, examining the interactions of resistance mechanisms

Keywords: Biodiversity, biotic resistance, invasive species, trophic interactions

Introduction & Background:

The introduction of species into non-native habitats has been of interest to ecologists since the 1950's[5]. Charles Elton notably hypothesized that higher diversity leads to greater stability and resistance to invasion[1]. Elton's hypothesis in combination with a global increase in the spread of species sparked the study of impacts of biological invasions[4,5,]. The idea of biotic resistance, or the ability of a native community to resist the success of invasions, has remained of great interest since its inception more than fifty years ago[1,2]. Scientists are specifically interested in determining why some communities are more resistant to invasion than others, for both ecological and economical reasons[4,5,11]. Biological invasions can have both beneficial and detrimental ecological effects thus, understanding the response of native communities to invaders is of particular importance for sustaining ecosystem function and services[5,8].
In effort to understand the processes governing invasion and resistance, ecologists have considered a great deal of potential mechanisms. Some of the most widely accepted mechanisms include biodiversity, invader traits and species interactions[2]. Biodiversity is thought to be an important mechanism theorizing, that a diverse assemblage of species will effectively monopolize available niche space, thus hindering the success of invading species[1,6]. There is great evidence that the specific traits of the invader dictate success or failure upon introduction[8,4]. In the natural world ecological communities are mediated by a suite of species interactions, both direct and indirect, some of which include competition, predation and facilitation[2,7,10]. It is also known that the trophic structure of a community can yield a great deal of information about its stability and diversity[2]. However reports in the literature on the relative influence of these mechanisms in general and across systems (i.e.: marine vs. terrestrial) are conflicting[4,5,12]. One goal of this study is to refine this inconsistency. Specifically, this study will focus on two of these commonly studied mechanisms, diversity and species interactions. Theory predicts that native biodiversity should increase resistance to invasion and additionally, diversity changes with latitude[5,6]. This broad definition of diversity may be problematic in this context as it has been suggested that predictions for ecosystem function based on one dimension of diversity are often unreliable[7]. I will examine both horizontal (number of species in a trophic level) and vertical (number of trophic levels) diversity to gain more insight about this biotic resistance mechanism. Secondly, it has been shown that native consumers and producers respond differently to competitive and consumptive effects of an invader[5]. Considering the trophic position of the invader may explain the differential responses of native species. The ability to gauge and ultimately predict the success and impact of invasive species has huge implications for mediating potentially destructive ecological effects and the subsequent economic consequences.

Questions & Goals:

I will develop theory examining the success of invasive species occupying different trophic levels along a diversity gradient in effort to better understand these mechanisms of biotic resistance.

1.) What are the effects of varying horizontal diversity in space and time on invasion success?
2.) What are the effects of varying vertical diversity in space and time on invasion success?
3.) Does trophic level of an invader play a critical role in amplifying or dampening abilities of natural communities to resist invasion?

4.) Is there an interaction between trophic level and diversity on invasion success?

Methodological Approach:

Using a set of differential equations I will develop a spatially explicit version of the Rosenzweig-MacArthur predator-prey model[3] with increasing trophic complexity. I will simulate community dynamics along a diversity gradient, such as latitudinal. The movement of species between patches will vary to mimic the differences between more open (marine) versus closed (terrestrial) systems. The first layer of the model will use a phenomenological approach, examining simple resource competition between basal level species, one native and one invasive. The second layer will incorporate apparent competition between an invasive meso-predator and a native meso-predator who share a common resource. The third and final layer will be an extension of this apparent competition module, which will include the addition of an invasive top-predator able to consume native meso-predators. Using this layered approach will allow me to isolate the effects of trophic position on invasion success. In order to differentiate between native and invasive species within the model, specific and ecologically relevant, growth, recruitment and survivorship rates will be specified for each the native and invasive species. The invasive predator will be simulated as a generalist predator using a Type III functional response. Simulations will run until the system reaches equilibrium. I will determine biologically relevant equilibrium solutions and assess the stability of each. All mathematical modeling, computer simulations and analyses will be conducted using the R programming environment.

Expected Results & Implications:

Testing the effects of species introductions across trophic levels and along a diversity gradient will elucidate how interactions between trophic position and diversity influence the success of established invaders. Many experimental manipulations in the invasion-biology literature identify diversity, as a mechanism of biotic resistance, however there is still some debate surrounding the weight of its impact. Modeling diversity in two dimensions (horizontal and vertical) may help clarify the role of this resistance mechanism. It is crucial that we gain a better comprehension of the patterns and mechanisms of biotic resistance, as it is fundamental to a general understanding of invasions. This study has broad implications as invasions are known to affect ecosystem processes[9], and ecosystem services supplement global economies, often in immeasurable ways[11], the preservation of ecosystem function is fundamental to the welfare of humans worldwide.

Literature Cited: [1] Elton, (1958); [2] Paine, *Am. Nat.* (1966); [3] Rosenzweig & MacArthur, *Am. Nat.* (1963); [4] Levine et al., *Ecology Letters.* (2004); [5] Kimbro et al., *Ecology Letters* (2013); [6] Stachowicz et al., *Science* (1999); [7] Srivastava & Bell, *Ecology letters* (2009); [8] Holt & Loreau, *Monographs* (2002); [9] Simberloff et al., *Trends in Ecology & Evolution* (2013); [10] Simberloff & Von Holle, *Biological Invasions* (1999); [11] Costanza et al., *Nature* (1997); [12] Freestone et al., *Ecology* (2011)