Forecasting spread and impact to inform pre-import decisions.

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Introduction

In a bioeconomic framework of addressing the threat of invasive species, one of the objectives my research program is to provide estimates of the regional economic and ecological impact an invasive species will potentially inflict upon a region. Achieving this objective requires addressing four steps: 1) estimate the potential habitat, 2) predict the spread, 3) estimate economic and ecological impacts, and 4) determine the regional consequences of spread through the economy and ecosystem. This summary focuses on the spread and ecological impacts of invasive species to help inform pre-import decisions.

Spread

The ability of species to spread is a result of their own natural dispersal capabilities and human-mediated (i.e. long-distance) dispersal. The ability of species to disperse naturally has been a long studied area of ecological research and can be modeled using diffusion models. Natural dispersal rates often result in a linear relationship between the distance spread by the organism and time. Long-distance dispersal events, on the other hand, result in exponential spread rate. Human-mediated dispersal on the other hand can result due to a multitude of pathways, including accidental transportation related pathways and organism in commerce (Lodge et al 2006, see Bossenbroek et al. 2007 for an example). One benefit of focusing on pathways is that the number of pathways is vastly smaller than the number of species. Because of this we can thus ask: What pathways are available to a particular species?
How effective might those pathways be in transporting the species? These questions may be more crucial than knowing natural dispersal rates.

Emerald Ash Borer Example

The emerald ash borer (*Agrilus planipennis*) is poised to wipe out native ashes (*Fraxinus* sp.) in North America with expected catastrophic losses to the ash tree forestry (MacFarlane and Meyer 2005). The emerald ash borer was first discovered in Detroit in 2002 and in a matter of only a few years has destroyed all ash trees within the Detroit Metropolitan area and spread through southeast Michigan and into northern Ohio. For the foreseeable future, the spread of the emerald ash borer will continue to destroy urban, forested and natural ash trees, causing substantial ecological and economic impacts.

To model the spread of emerald ash borer both natural and human-mediated dispersal need to be considered. Emerald ash borers can fly but rarely travel more than a few kilometers in any particular year. Human-mediated dispersal of the emerald ahs borer can result due to campers moving firewood, the wood products industry, or accidental hitchhiking on vehicles. With Dr. Louis Iverson of the U.S. Forest Service and our collaborators we are modeling the potential spread of emerald ash borer in Ohio and Michigan. Our preliminary results show the inclusion of human-mediated dispersal drastically increases the rate and risk of spread of emerald ash borer throughout Ohio compared to natural dispersal alone.

Gypsy Moth Example

The Gyspy moth was introduced into the Boston area by an entomologist that intentionally brought gypsy moth to the United State in the 1860s. In contrast to the rapid dispersal of the emerald ash borer, the gypsy moth has spread at a much slower rate and apparently in a manner that could be attributed to its natural capabilities. Even by the 1930's the gypsy moth was still contained with the New England States. There has been at least one drastic human-mediated dispersal event, which resulted in gypsy moth showing up in the state of Michigan.

Viral hemorrhagic septicemia (VHS) Example

The emerging disease, viral hemorrhagic septicemia (VHS), has caused massive and highly publicized fish die-offs in Lake Erie and other areas of the Great Lakes during the past several springs (Jones and Dettmers 2007). The spread of VHS cuts across dispersal pathways. Spread of VHS within the Great Lakes region occurs through two processes: natural diffusive spread via the movement of fishes; and human-mediated transport, potentially including ballast water discharge by ships, recreational boaters traveling overland from one Great Lakes boat landing to another and the movement of live bait. Live bait and thus diseases such as VHS often come from a supply chain including wild harvest within the Great Lakes, and then transport to retailers and anglers.

Impact

Invasive species cause a range of impacts when they are introduced including: effects on individuals, genetic effects, population dynamic effects, community effects, effects on ecosystem processes, and economic impacts. Despite these many impacts, there are few guidelines measuring impact. One measure was developed by Parker et al. (1999) based on the following equation:

$$I = R \times A \times E,$$

where, I is impact, R is the range of the species, A is the abundance of the species and E is some measure of the impact per individual or per unit of biomass suggest that the overall impact. Unfortunately, this measure of impact requires lots of data, which may not be even available in the native range.

A second approach is to assess the characteristics of species that are known to be invasive and ask the question: What species characteristics can be used to predict whether a species will become invasive (i.e. have a large impact)?

Fisheries Example:

Kolar and Lodge (2002) developed a decision tree method to predict whether a fish species could be successfully introduced into the Great Lakes or not. This analysis entailed identifying 24 species that had been successfully introduced (e.g. rainbow smelt) and 21 species that had been introduced into the Great Lakes but had failed to establish (e.g. atlantic salmon). For each of the species information on 23 traits were gather for each species from three general goups, including: habitat & environmental tolerances (7 parameters, e.g., temperature tolerances), life history characteristics (14 parameters, e.g., age at maturity) and history of invasiveness (2 parameters, e.g., invasive elsewhere). The results of the decision tree analysis had ~90% success rate in differentiating species that were successfully introduced compared to those that failed based on only a few of the traits that were measures.

Mollusc Example:

In a similar analysis, Keller et al. (2007) examined molluscs in the Great Lakes that are known to be invasive compared to those that are considered benign. They considered several traits, including reproduction, brooding, size, etc. The results showed that for this taxonomic group, the overall fecundity rate was the only trait needed to differentiate between the two groups at a 80% success rate.

Several other analysis have shown similar accuracy rate among terrestrial plants (Australia Pheloung 1995, 1999; Cont. US Reichard & Hamilton 1997; Hawaii Daehler et al. 2004; Pines Rejmanek & Richardson 1996) and birds (Sol et al. 2005). These analysis are quite accurate, however they require lots of basic natural history data, including data on the knowledge of successful/unsuccessful or invasive/benign species that can be compared. Data must also exist for the species that is going to be imported.

Conclusions

- Spread:
  - Developing models of human-mediated dispersal pathways should be a higher priority than natural dispersal.
  - What pathways will be available to species of interest?
- Impact:
  - Impact can be hard to define: ecological vs. environmental, types of impacts (i.e. population, community level, etc.)
  - What are the characteristics of the species that are invasive in a particular taxonomic group?

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