The Rich Get Richer: Plant Invasions in the United States and Canada.

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One of the most popular and contentious theories regarding biological invasions is that species-rich, productive, competitive habitats should be less vulnerable to invasion than species-poor, low productivity sites. Early observations by Charles Darwin (1859), and Charles Elton (1958) suggested that lack of intense inter-specific competition is a major force in structuring plant communities (MacArthur 1970). Theory suggested that an immigrating species would face strong resistance from many interacting species that monopolize available resources and create a stable community. Small-scale experiments (Knops et al. 1997; Naeem et al. 2000; Kennedy et al. 2002) and mathematical models (Case 1990) have generally supported this view. However, these experiments and models do not accurately reflect the natural environment, and ecologists have begun to question the paradigm of biodiversity impeding invasion by aliens (Levine and D'Antonio 1999).

For example, riparian zones are well-known hot-spots of biodiversity, and yet are prone to invasion by well known plants such as *Poa pratensis* (Kentucky bluegrass), *Elaeagnus angustifolia* (Rusian olive) and *Lythrum salicaria* (purple loosestrife). No doubt factors other than diversity lead to invasion of riparian sites: a few hypotheses could be resource richness such as light, water, and soil nitrogen promote alien as well as native growth; water is an effective dispersal mechanism for alien seeds; natural and human-originated disturbances such as water level, livestock grazing and movements by small mammals assist in alien seed germination. There is a paucity of data on the invasion of natural habitats by alien plants, and this talk outlines three such studies at a variety of scales from a comparison of 8 American States, to a comparison of 10 5-10 ha study plots in British Columbia's semi-desert south Okanagan, and 34 plots in Gros Morne National Park, Newfoundland and Labrador.

To compare the American States, plant diversity was sampled at two different scales: $1m^2$ and $672m^2$ plots. At the $1m^2$ scale, plots with more native species also had more alien species at 7 of the 8 states ($P = 0.003$ when combined). The same pattern occurred at the $672m^2$ scale, and this time the relationship was stronger: 4 states were significant [P (n) = 0.001 (81), 0.003 (44), 0.04 (33), 0.04 (15)]. Contrary to the theory detailed above, hot-spots of native plant diversity were being invaded.

Throughout the United States, the pattern of invasion was not that clear from county-level data, though hot-spots of invasion included New York, Florida, Louisiana and California. However, looking at individual states, an ominous pattern emerged. Very strong correlations were found between native and alien species in a county. Native species rich counties were being invaded in Alabama and throughout the United States: the rich were getting "richer".

Other factors are obviously at play here. Just as water serves as a conduit for seed dispersal for alien plants in riparian areas, so do the many roads in terrestrial systems. This was especially obvious for us at Escalante National Monument in Utah, where *Stephanomeria tenuifolia* (Russsian thistle) covers the newly graded roadsides. What is concerning is having a matrix of roads and riparian corridors in these natural areas: they serve as conduits for weed infestation.

In Canada, sites rich in native species were also richer with aliens: in the south Okanagan, sites with more native species also had more aliens, with a marginally significant correlation coefficient of 0.50 (P=0.14, n=10). Some of the variation in response was explained by subtle differences in elevation. Among the native species, there was increased species richness at higher elevations (r_s = 0.65, P = 0.04, n=10). Among alien plants, this relationship was not as strong (r_s = 0.46, P = 0.19, n=10).

At Gros Morne National Park in Newfoundland, Canada, sites rich in native species were also richer with aliens (r_s = 0.36, P = 0.01, n=34), though the relationship was not tight. In this case, the variation in response could be explained by disturbance level. Highly disturbed sites that were close to human disturbance and/or had been heavily transformed by humans had greater than expected aliens, compared with sites that had very few aliens that are in areas of low impact, regardless of biodiversity. The types of disturbance include: trail building with imported limestone gravel; clearcutting of domestic wood harvest blocks; and ungulate trails. Highly disturbed sites are associated with higher pH, more bare ground, and higher light levels. Native species richness is not correlated with these physical parameters, but alien species richness is (ie: for pH: r_s = -0.47, P = 0.001, n=34).

We can use this information to predict potential sites of new invasion, so that prevention and eradication are possible. Even at broad general levels, the relationship between native and alien species richness is helpful in this regard. At Colorado State University, we are developing powerful predictive “spatial models” or “ecological forecasting models” with the help of NASA Goddard Space Flight Center to predict invasion by alien species. The system has been used to map areas of invasion in National Parks and Monuments, so that land managers can focus efforts on a few species in a few areas. In a few years and with the help of NASA, we hope to offer web-based tools to mapping and predicting invasive species. And finally, we have established a new National Institute of Invasive Species Science – a virtual institute of agency and non-government groups – and are interested in collaborating at an international level.

Predictive modelling and rapid surveys are crucial to facilitate detection and eradication. It is necessary to get to alien populations early because once established, exotic plant species are difficult to eradicate. We cannot expect hotspots of native plant species richness to repel invasions. Our collective results show that the threats of species invasion are significant and predictably greatest in species-rich areas.

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