<u>Testing an Ecological *Cost* of Habitat Corridors: Spread of Invasive Species</u>

Key-words: conservation, habitat corridors, invasive species, ants

Background: As extensive tracks of habitat become fragmented, populations in the remaining habitat become isolated and increasingly vulnerable to extinction. A frequently touted solution is the creation or maintenance of habitat corridors – strips of habitat that connect otherwise isolated patches of the same habitat and that presumably increase animal movement between patches[1-3]. Although corridors make intuitive sense, their actual effectiveness remains controversial[4,5]. The controversy has arisen because: (1) studies frequently reach opposite conclusions[1], (2) the vast majority of studies are non-experimental, small-scale or poorly replicated[2], (3) confounding factors are often overlooked (e.g., the additional area and edge habitat that corridors inevitably bring with them)[1], and (4) corridors may facilitate the spread of invasive species[6].

I will test the effectiveness of corridors in restoring communities of native ants in a highly threatened ecosystem, longleaf pine savanna. I am fortunate to be able to address or overcome many of the above problems and constraints of previous studies. Specifically, I will be working in a series of experimental landscapes (Fig. 1) created in 1999 by my advisor (Doug Levey) and Nick Haddad (NC State). These landscapes are large (40 ha each, including buffer) and well replicated (n = 8). The rationale for their design is complex[1]. In brief, each contains five "patches" (ca. 1 ha) that have been planted with longleaf pine, wiregrass, and other characteristic species of longleaf pine savanna. The restoration process includes frequent burns. The matrix is densely planted loblolly pine plantation, which is generally a hostile environment for the species in young longleaf. Each landscape is comprised of one "central" patch and four "peripheral" patches. The central patch is connected to one peripheral patch by a 150m corridor. The other three peripheral patches are unconnected and are of two types, "winged" and "rectangular". The areas of winged and rectangular patches are equal to the area of the "connected" peripheral patch plus its corridor, allowing one to disentangle connectivity (corridor) effects and area effects. Likewise, the "edginess" of winged and connected patches is equivalent, allowing one to disentangle connectivity and edge effects.

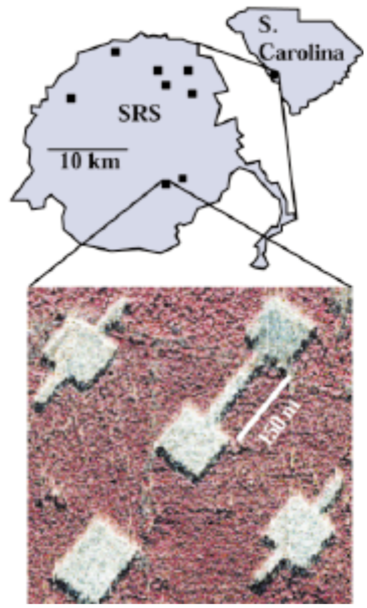

Figure 1: Savannah River Site (SRS) Corridor experiment. Patches are regenerating longleaf pine savanna. Upper right patch = "Connected "; Lower-right patch = "Winged"; Lower-left ="Rectangular". N = 8 of these sets

Although I did not participate in the design or creation of these landscapes, I've worked in them for eight months and have **crafted my own project**, focusing on ants (My advisor works on birds; this is my own work). I became enamored with ants while censusing them in my spare time last summer. They are unusually diverse in longleaf pine savanna[7], easy to observe, amenable to experimentation (e.g., removal), and can have major impacts on restoration of plant communities through their roles as seed predators[8] and dispersers[9]. Perhaps more intriguing, an exotic invasive species, the red imported fire ant (*Solenopsis invicta*) is abundant but patchily distributed within and among the landscapes. It's unclear whether corridors facilitate spread of fire ants and it's recently controversial whether fire ants are detrimental to native ants[10]. I will test for corridor effects on all ant species in the landscapes, holding area and edge effects constant. The truly unique aspect of my project will be my ability to assess the role of corridors in the spread of an invasive species and then to weigh potential costs of such spread (reduced species richness of native ants) against the presumed benefits (increased species richness of native ants). **No previous corridor project has examined the interplay between the spread of invasive and native species**, despite high-profile arguments for doing so[6]. I aim to fill the void.

Preliminary Work: *S. invicta* occurs in all eight experimental landscapes, but is extremely variable in density among patches, ranging from 3 to 34 colonies/ha (J. Resasco unpubl. data). I have conducted surveys of common ants and created a large reference collection of all species. More generally, I have previous experience with dispersal dynamics of invasive species[11]. (My application for this Fellowship last year received an Honorable Mention. My research statement was only "Very Good", largely because I had no experience in the landscapes at that time.)

Hypotheses: I hypothesize that **(H1)** *Corridors will increase species richness of longleaf pine savanna ants***.** **(H2)** *Corridors will increase abundance of* S. invicta*.* **(H3)** S. invicta *abundance will be negatively correlated with the species richness and abundance of native ants.* **(H4)** *Removal of* S. invicta *will increase the species richness and abundance of native ants.*

Methods: The experimental manipulation required for **H 1-3** has already occurred. Testing these hypotheses now requires data on spatial and temporal variation in ant abundance. I will census ants using two standard techniques: tuna bait stations (≈10g) and 70 mm diameter pitfall traps. To control for edge effects within patches, I will conduct these censuses at distances of 5, 10, and 20m from the nearest edge. These surveys will be done in May and September for four years (Years 1 to 4) to follow the temporal dynamics of longleaf pine restoration. To test **H4**, I will eliminate all *S. invicta* colonies from one peripheral patch of each type (connected, winged, rectangular) in each experimental landscape. This will leave the fourth peripheral patch (either winged or rectangular) as a control. Starting in Year 2, I will remove colonies as described in a recent study[10], repeating the treatment as needed to keep selected patches free of *S. invicta*.

Analyses: Tests of **H1** and **H2** will employ the same Mixed Linear Model used in previous studies at this site[1-3], with landscape as a random effect and patch type and distance to edge as fixed effects. Species richness will be standardized via rarefaction. **H3** will be tested via regression. **H4** will be tested as a Before–After-Control–Impact (BACI) design.

Broader Impacts: Many conservation plans simply assume that habitat corridors are effective[4]. Data are sorely lacking. My project provides an opportunity to integrate straightforward tests of corridor theory with restoration of a highly threatened habitat. Likewise, invasive species are often blindly assumed to have detrimental effects on native species, but *restoring native biodiversity may not be as simple as removing non-native species*[10]. My project will test the extent to which this is the case. Finally, the U.S. Forest Service is keenly interested in *applying* our results in their longleaf management plans at SRS -- I am already collaborating with them, attempting to bridge research and restoration. Apart from this project's broader impacts on conservation, I believe ecologists have a responsibility to educate the general public about their work. Such outreach is especially critical for children and youth from groups under-represented in science. I will use this project to bring new material to my current and future outreach activities (STEP and SPICE, respectively; see Personal Statement).

Literature Cited: **(1)** Tewksbury, JJ *et al.* (2002) *PNAS* 99, 2923–12926 (**2)** Townsend, PA and Levey, DJ (2005) *Ecology* 86, 466–475 (**3)** Damschen, EI *et al.* (2006) *Science* 313, 1284–1286 (**4)** Simberloff, D *et al.* (1992) *Conserv. Biol.* 6, 493–504 (**5)** Hilty, JA *et al.* (2006) Corridor Ecology. Island Press (**6)** Proches, S *et al.* (2005) *Science* 310, 779–783 (**7)** Lubertazzi, D and Tschinkel, WR (2003) *J. Insect Sci*. 3, 1–17 (**8)** Orrock, JL and Damschen, EI (2005) *Ecol. Appl.* 15, 793–798 (**9)** Ness, JH *et al.* (2004) *Ecology* 85, 1244–1250 (**10)** King, JR and Tschinkel, WR (2006) *J. Anim. Ecol.* 75, 1370–1378 (**11)** Resasco, J *et al.* (2007) *Int. J. Remote Sens.* 28, 3739–3745

Personal Statement

My career goal is to be a professor of ecology. In particular, I would like to work at an institution that values both research and teaching and that provides opportunities for mentoring students from diverse backgrounds. Such a position would allow me to integrate research and teaching, in the process awakening interest in ecology among students who, like myself four years ago, are looking elsewhere for career ideas. An NSF graduate research fellowship would allow me to focus my attention testing basic ecological theory about habitat corridors (Intellectual Merit), while simultaneously addressing an issue of central importance in management plans worldwide and continuing K-12 outreach activities in Florida and South Carolina (Broader Impacts).

My discovery of Science: For as long as I can remember I have had a fascination with the beauty of nature and the complexities of species interactions. Growing up in Argentina, Pennsylvania, and Oklahoma I was fortunate to have easy access to forests, pampas, and creeks, where I was captivated by the diversity of living things from snakes to crayfish. In high school as I began pondering careers, I unconsciously assumed that ecology was a dead end. In retrospect, this was because I didn't know any professional ecologists. At the University of Oklahoma I began as a chemical engineering major -- not because I had a particular interest in chemical engineering but because I believed that major would surely land me a "good job." By my sophomore year, I realized that choosing a major based on the job market or potential salary would just as surely land me a dissatisfying career. It was at that point (only 4 years ago!) that decided to pursue my childhood passion in ecology. I changed my major to zoology, was awarded an NSF-REU position (see Previous Research) and found a series of mentors who have kindled my interest in landscape ecology and fostered my belief that scientists need to do more than do science – they need to communicate their work to the general public and be enthusiastic role models to the next generation.

Importance of mentoring: My richest experiences have come from interacting with mentors. I've learned far more through informal conversations and pondering what they do than I've learned in any classroom. These mentors have had a profound effect on my quick metamorphosis from unenthusiastic chemical engineering student to ecological scientist. They have taught me how to design an experiment, think critically, write effectively, analyze data, and communicate with clarity and enthusiasm. They also motivated me to be a leader, to be conscious of scientific ethics, and to maintain an interdisciplinary and collaborative spirit. Because I've been mentored in mentoring, I now embrace the importance of being a mentor, myself. I am participating in the University of Florida's (UF) Undergraduate Research Assistantship Program (URAP), which pairs graduate students with undergraduates who pursue an independent research project. More far-reaching, I will spend two days per week next year, being a role model to underprivileged youth through an NSF GK-12 program (see below).

Fostering diversity in science from an early age: I recognize the need for mentors and role models at an early age, particularly for those from groups underrepresented in science. I am a Hispanic American and am committed to being an obviously enthusiastic role model for other minority students. Acting on this belief, I volunteered in the Ruth Patrick Science Education Center's Science and Technology Enrichment Program (STEP), which aims to foster children's interest in science and scientists. Side-by-side with kids from extraordinarily diverse backgrounds, we collected data on water quality and recorded the presence of various aquatic invertebrates. I will always remember the excitement and surprise of children looking through a microscope for the first time and discovering a damselfly nymph – a miniature monster! More important, the experiences of STEP convinced many of them that science was fun and allowed them to be scientists, at least for a day.

I am especially excited to continue such activities in 2008-09 as a "SPICE" Fellow. I've been accepted in SPICE (Science Partners in Inquiry-based Collaborative Education), an NSF GK-12 that trains graduate students in inquiry-based learning techniques and places them into under-resourced middle schools, where they become teachers, mentors, and role models for disadvantaged youth. This is a major commitment, involving intensive training and 2 days/week in the schools, all of which have large populations of minority students. As with STEP, students will become scientists every time I'm in the classroom. I love that SPICE Fellows are encouraged to be in-your-face role models. For example, they are called "scientists" (not teachers) by students and staff, and they wear bright polo shirts embroidered with the SPICE logo and – in large print – "I am a Scientist." Students quickly realize that scientists are not socially awkward people in lab coats and that science is a fascinating and dynamic process (not a collection of facts to be memorized for standardized exams). I firmly believe that this type of realization is critically important to both science and society.

SPICE will broaden me and influence those I teach in another fundamentally important way -- through providing a non-traditional approach to instruction. It's a curious fact of academia that although professors rapidly adapt their research techniques, they are often "stuck" in traditional habits of teaching. Practically all teach as they were taught and very few have any formal training in pedagogy. Consequently, going to class is synonymous with going to lecture. Yet, researchers in education agree that lecturing is not the best way to teach. Small group activities and inquiry-based approaches are far better. I believe that graduate education needs to find a better balance between training in research and training in teaching. I wholeheartedly embrace SPICE's goal of fostering graduate student teaching and communication skills, helping people like me break the cycle of traditional classroom instruction. Armed with the background in pedagogy that SPICE will provide, I am determined to become innovative teacher, exploring new techniques of instruction and integrating science and teaching.

Intercultural perspectives: One reason I chose to attend UF is its rich international community and critical mass of Hispanic American students. It ranks 5th nationally among AAU institutions in the number of PhDs awarded to Hispanics and is the lead institution an NSF AGEP (Alliance for Graduate Education and the Professoriate) program. The primary goal of AGEP is to increase the number of Hispanic and African Americans who enter tenure-track positions at research institutions. I am partially supported by AGEP ($5,000/year) and am a proud participant in its activities.

I empathize with the difficulty of crossing cultural and language barriers. I was born in Argentina and immigrated to the U.S. when I was six years old. Although I am fully integrated into the U.S. culture, I keep strong ties with Argentina, its people, and its customs. I keenly remember coming to the U.S., not speaking English and feeling a stranger at school. In time, I made a bilingual friend from Chile. Having such a friend made all the difference in the world, helping me adjust and feel at home. Remembering this, I have made an effort to help students from Latin America become accustomed to life in the U.S. I am doing so now with new graduate students in my department at UF and will do so next year with middle school immigrants in SPICE. *In this age of global environmental challenges such as climate change and disease pandemics, it is more important than ever to foster diversity in the workforce and provide strong intercultural perspectives.* I will be a part of that process!

Previous Research

"For what things we have to learn to do, these we learn by doing"
-Aristotle

As a young scientist I have taken this philosophy to heart. I aspire to always be a better researcher. On this journey I have actively participated in several research activities. These experiences have taught me the importance of a peer-reviewed research plan, methods that tightly address one's hypothesis, statistical skills, an extensive literature review, and good presentation techniques. Aside from building those skills, interactions with my research mentors have taught me about ethics and broader impacts, given me confidence in my abilities, and allowed me to taste the excitement of crafting a manuscript and shepherding it through the process of publication in a peer-reviewed journal. I'm hooked and determined to succeed.

Corridor Project research: Before starting my graduate program at the University of Florida, I worked for eight months in 2007 as a field technician on the "Corridor Project" at the U.S. Department of Energy's Savannah River Site (SRS) in rural South Carolina. The project aims to bridge the gap between testing theory about habitat corridors and applying the results to adjacent land managed by the U.S. Forest Service. I learned about it through riveting talks at scientific meetings and papers in prominent journals, including *Science*, *Nature*, *PNAS,* and *Ecology*. I was drawn to it because of my passion for conservation biology and applied ecology. My duties entailed preparing sites, sowing tens of thousands of seeds, planting thousands of seedlings in forty 1-ha sites and watering them by hand during a record breaking, summer-long drought. The seedlings were species of "special concern" in restoring the sites to longleaf pine savanna, and the goal was testing effects of landscape corridors and habitat edges on restoration success. This experience quickly shaped my plans for graduate work because I was encouraged to pursue independent projects during my "spare" time. I started by learning to identify ants and surveying the common species in all of the sites. I then used GPS to map Red Imported Fire Ant (*Solenopsis invicta*) and Harvester Ant (*Pogonomyrmex badius*) colonies. Observing ants and becoming familiar with their natural history, reading literature, and chatting with colleagues gradually yielded several ideas for a dissertation project (see Proposed Research).

To broaden the impact of my activities at SRS, I volunteered for The Ruth Patrick Science Education Center's Science and Technology Enrichment Program (STEP). With STEP I helped provide hands-on environmental activities, designed to encourage children to develop an interest in science. Students were bussed to SRS, where they spent the day in the field and a nearby classroom, doing inquiry-based lessons and temporarily becoming scientists. I was pleased to share my excitement for science and nature with these students – it was as much a part of that summer's scientific activities as the plants I tended and the ants I surveyed.

NSF-REU: In the summer of 2006, I participated in an NSF Research Experience for Undergraduates (REU) program at Miami University in Oxford, Ohio. The theme was ecology of human-dominated landscapes. I collaborated with another REU student (Alison Hale) and two professors (Drs. Mary Henry and David Gorchov). Our overall goal was to understand the invasion dynamics of a problematic understory invasive species, Amur honeysuckle (*Lonicera maackii*). We took an integrative approach, linking large scale datasets from remote sensing with small scale, on-the-ground vegetation sampling. Alison and I actively participated in both parts. I was primarily responsible for the remote sensing component, while she focused on vegetation analyses. I learned how to use Landsat TM and ETM+ satellite imagery to detect areas of high vs. low cover of *L. maackii*. As an understory shrub of deciduous forests, *L. maackii* is difficult to detect by satellite imagery because it is often hidden by tree canopies. We circumvented this problem by taking advantage of *L. maackii*'s relatively early leaf expansion and late leaf retention. We were able to determine the best time window to detect *L. maackii* through the canopy. In parallel, we collected data on *L. maackii* abundance in the field by direct observation (i.e., we "ground-truthed" the satellite imagery). The combined study was very successful – we developed and validated a technique for detecting this understory invasive species by Landsat in late autumn. I took leadership in writing a manuscript, which we submitted to the *International Journal of Remote Sensing* (Resasco *et al.* 2007). I also presented this project at an ecology seminar at the University of Oklahoma(OU), and at the joint meeting of the Ecological Society of America and the Society for Restoration Ecology in August 2007.

Undergraduate research at OU: As an undergraduate at OU, I conducted an independent research project under the tutelage of Dr. Jeff Kelly. The project focused on a possible diet shift in Ord's Kangaroo Rat (*Dipodomys ordii*), associated with C3 woody shrub invasion in grasslands historically dominated by C4 plants. In this case, we decided to conduct carbon isotope analyses on hair samples of museum specimens dating back to 1930 to determine whether a shift in isotopic signature from C4 to C3 was present. We quantified shrub invasion through aerial photographs from museum specimen trap-sites and dates. Also at OU, I volunteered in the Mammalogy collection at the Sam Noble Museum of Natural History from 2004 to 2005. To share my appreciation of nature and biodiversity I also volunteered at the Oklahoma BioBlitz! program from 2004 to 2006. BioBlitz! is an inventory of biological diversity hosted by the Oklahoma Biological Survey and aimed at K-12 students.

Mammal research in Mexico: I firmly believe that scientists should be effective communicators with the general public and across different cultures. Acting on this conviction, I participated in an international collaborative study of small mammal distribution and ecology in Colima, Mexico in the winter of 2004/2005. Being fluent in Spanish and familiar with the Latin American culture, I was able to foster a valuable scientific and cultural exchange with Mexican students and faculty. I hope to have this sort of exchange with international colleagues and collaborators throughout my career.

Peer-reviewed publication:

- **Resasco, J**, Hale, AM, Henry, MC, and DL Gorchov (2007) Detecting an invasive shrub in forest understory using remote sensing. *International Journal of Remote Sensing*. 28, 3739–3745.

Presentations:

- **Resasco, J**, Hale, AM, Henry, MC, and DL Gorchov, Detecting an invasive shrub in forest understory using remote sensing. ESA/SER Joint Meeting, San Jose, California. August 5-10 2007, Poster.
- **Resasco, J**, Hale, AM, Henry, MC, and DL Gorchov, Detecting the understory invasive shrub, Amur honeysuckle (*Lonicera maackii)* using remote sensing. Ecomunch Seminar, University of Oklahoma. October 10, 2006, Oral presentation.