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Author's Commentary: The Outstanding Scrub Lizard Papers

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Introduction

I recall watching the astronauts take the first steps on the Moon and the contagious euphoria that swept the country after such a remarkable technological achievement. Technology has not been idle in the last three decades, as we have witnessed many innovations that have truly changed the world.

Despite such achievements, human civilization is still completely dependent on natural systems. The anthropogenic systems that provide the life support for our people in space are no substitute for the natural systems that sustain the billions on earth. The natural ecosystems that provide clean air and water, food, and shelter, are unlikely to be replaced by technological systems in the foreseeable future. These natural systems must be maintained to preserve our existence.

Anthropogenic systems have one major advantage over natural systems: Their status is easily monitored with calibration instruments that we know and understand because we built them. Thermostats, carbon monoxide detectors, and computer-controlled fuel injectors are commonplace on modern automobiles. Such calibration instruments are difficult to recognize for natural systems. We must rely on our incomplete understanding of natural systems to identify when these systems are endangered. Consequently, we often find ourselves creating costly environmental problems.

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The Fragmented Landscape of Southern Florida

As one example, human activities have endangered the fresh water resources in Southern Florida. Upland habitats provide a vital function in water regulation and purification. The summer rains supply fresh water to Southern Florida and percolate through the upland soils on their way to the wetlands and swamps that act as natural reservoirs.

However, these uplands are also ideal locations for urban development and citrus agriculture. Consequently, urbanization and citrus agriculture have converted the major portion of upland habitats. Now the summer rains are augmented by agricultural runoff and especially by runoff from heavily fertilized lawns and golf courses. The downstream reservoirs, both natural and human-made, are suffering from eutrophication effects such as oxygen depletion and changes in microbial activities.

Florida and federal taxpayers are now paying hundreds of millions of dollars to design and implement a water-management system that saves the fresh water needed by Floridians and saves national treasures such as the Florida Everglades. Although the urban and agricultural development is undoubtedly an economic boom for Florida, we are now paying for the unaccounted cost of disturbing a vital natural system.

Had we an instrument to assess the impact, we might avoid further damage to this natural water system and the consequent cost of rectifying the damage. Also, such an instrument might have prevented the problem by indicating how much development was possible before experiencing significant damage.

Biodiversity may provide a barometer for assessing the impact to natural systems. Biodiversity can be considered the sum total of all the genes, species, and ecosystems that exist on our planet. Because everyone can relate to what a species is, biodiversity is often thought of in terms of species diversity. It logically follows that if all species are persisting in a natural system, then the system must be stable. Unhealthy systems experience a decrease in biodiversity.

The Florida Scrub System

The Florida scrub system is part of the mosaic of ecosystems that cover the peninsula of Florida. Scrub is a xeric (dry) upland system surrounded by the more hydric (wet) systems that dominate the South Florida landscape. Scrub is patchily distributed across the Florida landscape, occurring only on well-elevated, well-drained areas such as ancient sand dunes. Florida scrub contains the highest number of endemic species (species found in no other type of habitat) for any terrestrial ecosystem in the Southeastern United States and thus has high biodiversity. Unfortunately, because of the destruction of scrub habitat, many of these species are listed as endangered or potentially

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endangered. The Florida scrub lizard (*Sceloporus woodi*) is one such species.

Because of our poor understanding of ecological processes, we do not know how much scrub habitat is required to maintain scrub biodiversity. In fact, it is difficult for us to predict how much habitat is necessary to maintain even a single species. We are only beginning to understand the processes that influence species distribution patterns. We hope that by focusing on one or a few species, we can ultimately piece together an understanding of processes that influence overall biodiversity. If we can successfully model and predict trends in scrub lizard populations, we can better understand the processes important to the persistence of scrub lizards. More important, by understanding the habitat distribution needs of the Florida scrub lizard, we can better appreciate the needs for all scrub organisms.

Such a problem requires an integrative approach. The scrub lizard thrives in habitat that exists in patches across the Florida landscape. This spatial component requires researchers to understand not only ecological processes inside scrub patches but also processes that influence the dispersal of lizards between scrub patches. To achieve success, population biology, landscape ecology, computer modeling, and mathematics have to be integrated. This was the problem presented to students in this year's Interdisciplinary Contest in Modeling.

Formulation of the Contest Question

In 1994, the Department of Defense provided funds to conduct amphibian and reptile surveys on the Avon Park Air Force Range (APAFR). This area is set aside for bombing practice for military aircraft and ironically contains some of the best-preserved scrub habitat in Florida.

Scrub organisms are fire-adapted. In fact, many scrub organisms cannot persist without periodic fires that thin dense, senescent vegetation and open up areas of open sandy habitat. Not only are fires allowed to burn on APAFR, the natural resource staff initiates periodic controlled burns to help manage scrub habitat. Because of private land issues elsewhere in the state, prescribed burning is seldom employed and the scrub habitat suffers.

My colleagues (Lyn Branch and Brad Stith of the University of Florida) and I were awarded funds to survey for rare and endangered species on APAFR. We immediately recognized the potential to collect valuable demographic, dispersal, and habitat data concerning the Florida scrub lizard.

We mapped all 95 scrub patches on APAFR: We used a geographic information system (GIS) and infrared aerial photos to delineate the boundaries of the patches, calculate patch areas, measure vegetation density, and construct digitized maps of the landscape. We conducted surveys in each patch to determine the presence of scrub lizards and to establish a baseline to compare occupancy patterns with patterns predicted by mathematical models. We also established eight trapping grids, each one hectare in size, in eight different patches that ranged in size from 11 to 278 hectares. These trapping grids were visited ev-

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ery month for two years; mark/recapture techniques allowed us to estimate density, survivorship, and fecundity (birth rate) for lizards in all eight patches.

We also conducted dispersal studies. Although radio telemetry can provide direct measurements of dispersal behavior, scrub lizards are too small to burden with typical radio transmitters. Smaller transmitters cost too much to afford the hundreds necessary to get large sample sizes, and the batteries last for only a few weeks. We assessed dispersal indirectly. We simply marked hundreds of lizards, released them, and walked transects to recapture lizards up to months after their release date. The distance to the release site was recorded for each recaptured lizard. In this manner, we could estimate how distance from the release site was associated with recapture rates. We also tested lizards in enclosures to assess how effectively they moved through different types of vegetation and across water barriers.

This initial research was the source for all of the data provided in the Contest, and the students were assigned the task of modeling a *metapopulation* (group of populations connected by dispersal) of scrub lizards on the north end of the APAFR.

Although my colleagues and I had published a logistic regression model using the same data [Hokit et al. 1999], the model was static and did not include dynamic demographic and dispersal processes. We recently published the results of two dynamic models [Hokit et al. 2001], but both models include very general assumptions about population demographics. For example, one model assumes that vital rates (survivorship and fecundity) are equivalent for different patches. This simplifying assumption makes the modeling easier but does not incorporate what we know from other analyses: Patch size is positively correlated with survivorship, fecundity, and density.

Thus, it was up to the students to design a spatially explicit (specific for a particular landscape), dynamic landscape-scale metapopulation model that incorporates patch specific vital rates and dispersal. Such a model has yet to be published for any species on any landscape, so the Contest was truly an original challenge for the students. Furthermore, students were required to address policy and management issues concerning the scrub lizard and Florida scrub habitat.

Response to Student Solutions

I was genuinely impressed with the student solutions to the problem. The creativity and range of approaches were remarkable. I was amazed at how different approaches resulted in well-thought-out and highly accurate solutions. I could gauge the accuracy of the modeling solution by testing the model predictions against known occupancy patterns for the APAFR landscape. Many models were within one or two patches of "predicting" the actual occupancy patterns on the landscape.

Many papers introduced me to new perspectives and approaches for such

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modeling problems; as a result, I'm motivated to learn new modeling strategies. Some papers utilized a traditional Leslie matrix coupled with dispersal models. Others used an incidence function approach. Still others incorporated neural-net modeling and polygonal representations of the actual landscape. The polygons were then used to model not only dispersal rates but also the probabilities associated with the direction of dispersal.

Including dispersal dynamics was one of the more challenging aspects of the problem. Given the crude nature of the dispersal data (e.g., recapture rates vs. distance from release site), it was a challenge to estimate survival probabilities for lizards moving between patches. Although seemingly simplistic, many papers arrived at the assumption that survival probabilities were probably correlated with recapture probabilities. Many animal studies have demonstrated just such an association between recapture and survival probabilities. Currently, we can only assume that the same is true for scrub lizards.

The best papers integrated policy and management options with their metapopulation model, resulting in prescribed treatments for specific habitat patches. These papers not only predicted which patches could support scrub lizard populations but also created a schedule of controlled burns to enhance and maintain scrub habitat. This approach combined the best science, math, and policy to arrive at a truly integrative and interdisciplinary solution.

Conclusions

The problem faced by the Florida scrub lizard is not unique. Many species are endangered due to habitat destruction and fragmentation. Although not as newsworthy as global climate change, ozone depletion, or acid rain, habitat destruction is by far the leading threat to biodiversity (although the former factors may lead to habitat destruction). Some estimates project that without careful management of habitat destruction, 10% to 20% of extant species will go extinct within the next few decades. Extinction balanced by complementary speciation (evolution of new species) presents no great risk to species diversity. However, an extinction rate of 10% to 20% over a few decades rivals major extinction events of the past, including the one that saw the demise of the dinosaurs. Thus, it is the rate of extinction, not extinction itself, which is problematic. A high rate of extinction will jeopardize biodiversity. If biodiversity is an accurate barometer of ecosystem health, we may be jeopardizing more than the scrub lizard's future.

There is much work to be done before we can be confident that our modeling strategies are accurate, robust, and generally applicable to many species. We are only beginning to understand the subtlety of the processes that act across spatial and temporal scales to influence the distribution of species and the functioning of natural systems. With such talented and well-motivated students, we may reach sufficient understanding to allow for the continued maintenance of our life-support system.

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About the Author

D. Grant Hokit is Associate Professor of Biology at Carroll College (Montana), where he has been since 1996. He has a B.S. (1986) from Colorado State University in Wildlife Biology and a Ph.D. (1994) in Zoology from Oregon State University, where he did amphibian research in behavioral and population ecology, including research on UV-b radiation and amphibian declines. He did a post-doc in Wildlife Ecology and Conservation at the University of Florida from 1994 to 1996, where he engaged in scrub lizard landscape ecology research.