

Droctonus frontalis, is an outbreak species capable of causing massive mortality within pine forests. It routinely vectors three species of fungi into trees. Two fungi (*Ceratoystiopsis ranaculosus* and *Entomocorticium* sp. A) are transported in specialized mycangia and are mutualistic with the beetle. The third fungus, *Ophiostoma minus*, which appears to be an antagonist of the beetle, is carried phoretically on the beetle exoskeleton, as well as by mites that are themselves phoretic on the beetles. Mites can also transport *Ceratoystiopsis*. The mycangial fungi differ in their ability to exclude *O. minus* from larval galleries, as well as in their benefits to the beetle and phoretic mites. We hypothesize that the population dynamics of *D. frontalis* are influenced by negative feedback from interactions involving *O. minus*, phoretic mites and mycangial fungi. We surveyed natural infestations to test patterns of association among species. We found a positive relationship between mites and *O. minus*, and an inverse relationship between beetle survival and *O. minus*. We also found strong seasonal patterns: abundance of mites and *O. minus* increased from spring to winter, as did the abundance of *Ceratoystiopsis* relative to *Entomocorticium*. We predict that a particular threshold density of mites and *O. minus* exists that would result in the eventual crash of beetle populations.

HOLLAND, J. N.,^{1,*} DONALD L. DEANGELIS² and JUDITH L. BRONSTEIN.³ ¹ UNIVERSITY OF MIAMI, P.O. BOX 249118, CORAL GABLES, FLORIDA 33124; ² U.S. GEOLOGICAL SURVEY/BIOLOGICAL RESOURCES DIVISION, P.O. BOX 249118, UNIVERSITY OF MIAMI, CORAL GABLES, FLORIDA 33124; ³ UNIVERSITY OF ARIZONA, TUCSON, ARIZONA 85721. **Population dynamics and mutualism: Functional responses of benefits and costs.**

We develop an approach for studying population dynamics resulting from mutualism by employing functional responses based on density-dependent benefits and costs. These functional responses express how the population growth rate of a mutualist is modified by the density of its partner. We present several possible dependencies of gross benefits and costs, and hence net effects, to a mutualist as functions of the density of its partner. Net effects to a mutualist are likely either a monotonically saturating or unimodal function of the density of its partner. We show that fundamental differences in the growth, limitation, and dynamics of a mutualistic population can occur when the net effects to that population are either linear, saturating, or unimodal with the density of its partner. We use the obligate mutualism between senita cactus and its pollinating seed-eater moth as an example to show the influence of different benefit and cost functional responses on the population dynamics and stability of the mutualism. Two mechanisms that may alter these benefit and cost functional responses are investigated: non-random distribution of moth eggs among flowers and fruit abortion by cacti. We show that differences in benefit and cost functional responses alter the stability of this mutualism. In particular, fruit abortion may allow for a stable equilibrium point, where none could otherwise exist, when active pollination is behaviorally associated with oviposition, and eggs are laid evenly among flowers.

HOLLAND, MARJORIE M.,^{*} LISA C. STRONG and MOLLIE SMITH. University of Mississippi, University, MS 38677. **Ecological assessment of riverine headwater environments.**

Determination of the specific action of natural and anthropogenic disturbance and the interaction of disturbance with other biotic and abiotic factors is a priority in ecological research: implicit in this general problem is also the question of how to detect change in ecological systems against a background of substantial variability. Our work in a headwater system has used various measures of biological diversity to assess natural and anthropogenic influences in USA forested systems in the mid-South. A land use management plan adopted for The University of Mississippi Field Station encourages continued use of disturbed areas and nonuse of unique habitats. Permanent plots were marked and overstory and understory species were sampled, starting in 1996. Dominant species of the overstory include *Liquidambar styraciflua* [Sweet-gum], *Quercus alba*, and *Pinus taeda* [Loblolly Pine]. While far more native species were sampled than non-native on the understory, the most frequently sampled is *Lonicera japonica*, a non-native woody vine. "Weedy" adventives appear to dominate areas of greatest human use. Effectiveness of the land use plan is discussed.

HOLMES, WILLIAM E.* and DONALD R. ZAK. UNIVERSITY OF MICHIGAN. **Indications of increasing soil C storage under elevated CO₂ and O₃.**

Enhanced plant growth under elevated CO₂ could lead to increased storage of C in terrestrial ecosystems as CO₂ accumulates in the Earth's atmosphere. This effect may be dampened by elevated atmospheric O₃, which decreases photosynthesis and plant growth. Soils are substantial pools of C in most terrestrial ecosystems, but the degree of variability in soil C precludes detection of short-term changes in soil C storage. We used a ¹⁵N tracer technique to follow the flow of N from soil solution into microbial biomass and soil organic matter as a tool to quantify changes in soil C storage. We collected soil beneath *Populus tremuloides*, *Betula papyrifera*, and *Acer saccharum* growing under experimental atmospheric CO₂ and O₃ treatments in a FACE experiment in northern Wisconsin. Ozone had no effect on ¹⁵N recovery in microbial biomass or soil organic matter at ambient CO₂; O₃ effects at elevated CO₂ varied by species. Elevated CO₂ significantly increased ¹⁵N recovery in microbial biomass and soil organic matter. Recovery of ¹⁵N in these pools was significantly greater under *Populus tremuloides* and *Betula papyrifera* than under *Acer saccharum*. These results indicate greater amounts of N were incorporated into soil organic matter under elevated CO₂ and this effect was species specific. Because soil C:N did not differ among treatments, our results suggest that greater plant growth under elevated CO₂ has increased rates of soil organic matter formation.

HOLT, CARRIE A.^{1,*} and NORMAN D. YAN.^{1,2} ¹ York University; ² Ontario Ministry of the Environment. **Recovery of zooplankton communities from acidification in Killarney Park, Ontario, 1972-2000: pH 6 as a recovery goal.**

Acidification of lakes has resulted in severe environmental damage including decreases in species richness and loss of sensitive species. Reductions in SO₂ emissions have allowed pH's of some lakes to rise above 6, a threshold of biological damage above which communities are considered "healthy". Nowhere has this rise been more evident than in Killarney Park (Ontario). Temporal trends in zooplankton species richness and composition were examined between 1972-2000 in 46 Killarney lakes to assess the biological recovery in lakes with significant water quality improvements (i.e. pH now >6) compared to 2 groups: (1) lakes which were never acidified, and (2) lakes which are still acidified (pH < 6). Recovery was not documented in species richness. Time trends in species richness could not be distinguished among the 3 groups of lakes. However, the community composition of lakes in which pH recovered to pH > 6 changed from a "damaged" state to a community type typical of neutral lakes. Some recovery was documented in the acidic lakes (which experienced change in median pH 4.6 to 5.0). Though these lakes did not recover to a state typical of neutral lakes, they experienced greater community change towards recovery than the other 2 groups. These results suggest that: (1) recovery to community types typical of neutral lakes does occur as lakes increase to pH > 6, and (2) the recovery process is non-linear, occurring at different rates along the pH gradient.

HOLUB, SCOTT M.* and KATE LAJTHA. Oregon State University. **The fate and retention of organic and inorganic nitrogen in a western Oregon coniferous forest.**

Organic nitrogen from the N₂-fixing epiphytic lichen, *Lobaria oregana*, contributes up to 80% of new N inputs in Pacific Northwest old-growth forests. Our objective was to determine the ecosystem pools involved in the retention of complex organic N inputs and to compare those results with inorganic N over the course of one year in a mid-elevation old-growth forest at the H.J. Andrews LTER. We added ¹⁵N-labeled *Lobaria*, bread yeast, tannin-complexed yeast, and NH₄Cl separately to large in situ soil cores. Upon collection, each core was separated into understory plant, moss, litter/O horizon, 0-5 cm soil, and 5-15 cm soil pools. All pools were analyzed for total ¹⁵N. Litter and 0-5 cm soil pools were also analyzed for inorganic N, DON, and microbial biomass N. Selected 0-5 cm soils were separated using density fractionation. Total ¹⁵N recovery over all dates was not significantly lower than 100%. For all treatments, the litter/O horizon was the largest sink for the added N, although the mineral soil horizons

tended to increase as a sink through time. Little of the total ^{15}N was found as inorganic N. The light and heavy density fractions showed similar ^{15}N labeling, which indicated that the sink strength per N molecule was similar in both fractions. Our results indicate that the soil pools at our site at H.J. Andrews have substantial ability to retain organic and inorganic N forms.

HOOPE, MARTHA F.* UC Berkeley. What should we look for in an invasive competitor?

Attempts to predict which species will become invaders have not been very successful. Conservation managers typically look for restriction, replacement, or exclusion by a non-native species to identify invasive species with the most impact on native species. Unfortunately, examinations of pattern alone often reveal invaders too late. Non-native competitors with strong effects on a single life history stage may cause declines in native species but coexist with them for a period of time. Here we suggest two types of competitors that can invade a system. The first, a "selective invader" does extremely well in a small range of high quality habitats and excludes native competitors from all but refuge habitats. The second, a "twin invader," matches a native species in its habitat requirements. If twin invaders have strong effects on reproduction or survival, they can exclude native species from a broad range of habitats and possibly cause extinction. Through examinations of data on the spread of invasive species and their impacts on native species in the United States, it appears that conservation priority should be given to twin invaders over selective invaders. This result suggests that apparent coexistence should raise as many red flags for conservation managers as the classic checkerboard pattern of non-native species excluding native species.

HOOTEN, MEVIN B.,^{1,*} DAVID R. LARSEN¹ and CHRISTOPHER K. WIKLE.^{2,1} ¹Department of Forestry / University of Missouri; ²Department of Statistics / University of Missouri. Modeling and mapping the distribution of ground flora in the Missouri Ozarks.

Forested systems of Southeast Missouri are home to some 500+ species of plants. Research has proven that the occurrence of certain plants is correlated with several site-defining variables. The Missouri Ozark Forest Ecosystem Project, designed to study long-term management effects on forests, collects landscape level floristic data at many spatial scales. The purpose of our research is to create a robust methodology for modeling organisms on a landscape using MOFEP ground flora data. Analysis of the spatial structure for several understory plants has shown that in addition to environmental effects, the distribution of species is influenced by uncharacterized spatial random effects. Using a hierarchical Bayesian framework we have accounted for these effects as well as uncertainty related to the change of spatial support between observation and prediction scales. This methodology has successfully allowed us to map the patterns of several species in the genus *Desmodium* by utilizing posterior distribution information gained from the model. Similar but separate data collected in the MOFEP area has been useful in performing preliminary evaluation of model accuracy and extent of application. Potential applications of this type of model include but are not limited to: Spatio-temporal mapping of wildlife forage availability, analysis of interspecies spatial interaction, landscape level identification of areas susceptible to exotic invasion, analysis of spatial and temporal patterns of biodiversity.

HOOVER, JEFFREY P.* Illinois Natural History Survey. Decision rules for Prothonotary Warblers: the influence of nesting success on site fidelity.

Several hypotheses have been proposed to explain patterns of avian site fidelity but there is little consensus concerning the ultimate causes. I studied populations of Prothonotary Warblers (*Protonotaria citrea*) breeding in bottomland and swamp forests in southern Illinois, USA from 1994-2000 and experimentally manipulated the nesting success of randomly chosen pairs of warblers (1997-1999) to test two hypotheses that may explain patterns of between-year breeding-site fidelity in migratory songbirds. The two hypotheses that I considered were: (1) the Decision Rules Hypothesis, which states that patterns of between-year site fidelity are a result of experience-based choices (decision rules) by individuals and not simply a result of differential mortality; and (2) the Renesting Stress Hypothesis, which states

that individuals experiencing high rates of nest predation also experience an increase in stress associated with renesting resulting in higher between-year mortality and lower rates of return. Females returned at rates of 19, 53, and 81%, and males at rates of 42, 58, and 83% for individuals producing 0, 1, or 2 broods, respectively. The territory fidelity of those individuals that returned also increased with increased reproductive success. Other factors such as mate fidelity, age, sex, and brood parasitism by cowbirds had relatively little influence on between-year returns and territory fidelity. These results support the Decision Rules Hypothesis and demonstrate a causal relationship whereby individuals use their own reproductive experience at a site to assess the current and potential future quality of the location and respond accordingly by returning or not returning to sites and territories. The renesting stress hypothesis was not supported. Decision rules may allow these birds to avoid chronically high rates of nest predation by not returning to areas where nest predation prevents nesting success.

HOPE, DIANE,^{1,*} CORINNA GRIES,¹ WEIXING ZHU,² STEVEN CARROLL,¹ LINDA STABLER,¹ CHARLES L. REDMAN,¹ NANCY B. GRIMM¹ and ANN KINZIG.¹ ¹Arizona State University; ²SUNY Binghamton. Landscape pattern and process of an urban ecosystem: an integrated field inventory approach.

Incorporating the integral role of humans in landscape pattern and process poses unique challenges in cities. We used an extensive field survey and integrated inventory to sample an entire urban ecosystem (6387 sq. km), consisting of the urbanized, suburbanized and agricultural areas of metropolitan Phoenix and the surrounding desert. The inventory was conducted in spring 2000 at 204 sample plots (30m x 30m) located randomly using a tessellation-stratified dual-density sampling design. Objectives were a) to characterize patches in terms of key biotic, physical, chemical and socioeconomic variables and b) to examine relationships between land use, plant diversity, soil nutrient status and socio-economic indices along an indirect urban gradient. As predicted urbanization markedly increased plant diversity with three times the number of genera in urban versus undeveloped desert patches. We also hypothesized that urbanization would result in an urban to desert gradient in soil chemistry and that land use would explain much of the variation in soil nutrient pools. While inorganic soil nitrogen content was significantly higher in urban and agricultural patches compared with undeveloped desert (mean nitrate-N content of 45.4, 86.7 & 6.6 mg/kg respectively), patch type alone was not an adequate predictor either of soil nitrogen or organic matter content. This study constitutes a novel approach to quantifying ecological and social characteristics of extremely heterogeneous landscapes and will be repeated every 5 years as part of CAP LTER's monitoring program.

HORSLEY, STEPHEN B.,^{1,*} ROBERT P. LONG² and PAUL R. LILJA.³ ¹USDA Forest Service, NRS, Irvine, PA; ²USDA Forest Service, NRS Delaware, OH; ³Pennsylvania Dept. of Conserv. and Natural Resources. Effects of fence, herbicide, and lime on regeneration of sugar maple in northern Pennsylvania.

Sugar maple regeneration is not abundant in northern Pennsylvania forests despite the abundance of sugar maple in the overstory. In 1985, an experiment was initiated to determine the role of deer, interfering vegetation and acid soil on sugar maple regeneration. Treatments with and without fence, herbicide (2.2 kg ai. ha⁻¹ glyphosate), and lime (22.4 Mg ha⁻¹ dolomitic limestone) were installed in a split-plot experiment at 4 sites and all areas were thinned to 50% relative density. Treatments were evaluated for 10 years. Few sugar maple seedlings were present at the beginning of the experiment. Two sugar maple flower and seed crops occurred during the experiment, one in 1989 and one in 1992; all were larger on limed than on unlimed areas. These seeds fell into areas with vegetation established 5-8 years earlier. Sugar maple seedling abundance was positively correlated with overstory sugar maple basal area and with the abundance of grass ground cover; seedlings were more abundant on unfenced than fenced and limed than unlimed areas; herbicided and unherbicided areas had similar numbers of seedlings. Percent seedling survival was highest on limed and herbicided areas; fenced and unfenced treatments had similar survival. Height development was promoted by lime, but not fence or herbicide. Foliage of limed seedlings had higher concentrations of P, Ca, Mg, molar ratios of Ca:Al, Mg:Mn, lower Mn and similar aluminum compared with unfenced seedlings.



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