CTFS and STRI proudly present the 2005 CTFS Symposium

Forest Dynamics Research around the Globe
June 4 - 5, 2005
Earl S. Tupper Conference Center, STRI
Panama City, Republic of Panama

Symposium Schedule and Abstracts

This Symposium is supported by CTFS, STRI, and the US National Science Foundation
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Symposium Schedule

(Auditorium, Earl S. Tupper Conference Center – STRI)

Saturday Morning, June 4th, 2005

Moderator: Stuart Davies

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<td>Registration</td>
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<td>8:45 a.m.</td>
<td>Inauguration</td>
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<td>Mark Wishnie</td>
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<td><em>Center for Tropical Forest Science</em></td>
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<td>9:00 a.m.</td>
<td><strong>Center for Tropical Science: What next?</strong></td>
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<td></td>
<td>Peter Ashton. <em>Distinguished contributor</em></td>
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<td>Harvard University</td>
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<td>9:25 a.m.</td>
<td><strong>The role of mathematical theory in tropical forest ecology</strong></td>
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<td>Egbert Leigh. <em>Distinguished contributor</em></td>
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<td>Smithsonian Tropical Research Institute</td>
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<td>9:50 a.m.</td>
<td><strong>Habitat associations around the globe</strong></td>
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<td>Kyle Harms</td>
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<td><em>Louisiana State University</em></td>
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<tr>
<td>10:15 a.m.</td>
<td><strong>Long-term seed persistence facilitates species coexistence in tropical forests</strong></td>
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<td>Jim Dalling</td>
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<td><em>University of Illinois, Urbana-Champaign</em></td>
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<td>10:35 a.m.</td>
<td>Coffee Break</td>
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<tr>
<td>11:00 a.m.</td>
<td><strong>Effects of soil borne resources in tree distributions in three Neotropical forest plots</strong></td>
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<td>Robert John-Chandran</td>
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<td><em>University of Illinois, Urbana-Champaign</em></td>
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<td>11:25 a.m.</td>
<td><strong>Seasonal variation in irradiance is a dominant influence on tropical flowering and fruiting phenologies</strong></td>
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<td>Jess Zimmerman</td>
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<td><em>National Science Foundation</em></td>
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<td>11:50 a.m.</td>
<td><strong>Ecosystem decay of Amazonian forest fragments</strong></td>
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<td>William Laurance</td>
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<td><em>Smithsonian Tropical Research Institute</em></td>
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<td>12:15 p.m.</td>
<td>Lunch</td>
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<tr>
<td>1:15 p.m.</td>
<td><strong>Poster session</strong></td>
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Saturday Afternoon, June 4th, 2005

Moderator: Stuart Davies

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<tr>
<th>Time</th>
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<tr>
<td>1:45 p.m.</td>
<td>Density dependent mortality and growth of established seedlings in the BCI 50-ha Forest Dynamics Plot</td>
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<td></td>
<td>Liza Comita</td>
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<td><em>University of Georgia</em></td>
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<tr>
<td>2:10 p.m.</td>
<td>A comparison of seedling dynamics among three CTFS sites</td>
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<td>Margaret Metz</td>
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<td><em>University of California – Berkeley</em></td>
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<td>2:35 p.m.</td>
<td>Hasta los palos del monte...&quot;: Spatial distribution and seedling success in three Nicaraguan rainforest trees</td>
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<td>Douglas H. Boucher</td>
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<td><em>Hood College</em></td>
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<td>3:00 p.m.</td>
<td>Modeling gap regeneration in tropical forests</td>
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<td>Toby Mathews</td>
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<td><em>University of Aberdeen</em></td>
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<td>3:25 p.m.</td>
<td>Coffee Break</td>
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<tr>
<td>3:50 p.m.</td>
<td>Pulliam effects and size-related diversity changes in a lowland tropical rainforest</td>
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<td>Matthew D. Potts</td>
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<td><em>Institute on Global Conflict and Cooperation</em></td>
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<td>4:15 p.m.</td>
<td>Genetic evidence that successful long distance seedling recruitment is commonplace in a vertebrate-dispersed Neotropical tree</td>
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<td>Denise Hardesty</td>
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<td><em>University of Georgia</em></td>
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<td>4:40 p.m.</td>
<td>Seasonal and interannual canopy changes on Barro Colorado Island derived from Remote sensing</td>
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<td>Stephanie Bohlman</td>
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<td><em>Smithsonian Tropical Research Institute</em></td>
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<td>5:05 pm</td>
<td>Cocktail</td>
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Sunday Morning, June 5th, 2005

**Moderator: Richard Condit**

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<tr>
<th>Time</th>
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<tr>
<td>8:45</td>
<td><strong>Assessment of soil-water interactions at the plot scale in tropical landscapes</strong></td>
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<td>Robert Stallard. <strong>Keynote Speaker</strong></td>
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<td><em>Smithsonian Tropical Research Institute and USGS</em></td>
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<td>9:25</td>
<td><strong>Species drought resistance shapes local and regional species distribution patterns in tropical</strong></td>
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<td>Bettina Engelbrecht. <em>Smithsonian Tropical Research Institute</em></td>
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<td>9:50</td>
<td><strong>Leaf hyperspectral optical scans for rapid tree ecophysiological surveys: comparative results</strong></td>
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<td>from three CTFS sites.</td>
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<td>Sean Thomas. <em>University of Toronto</em></td>
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<td>10:15</td>
<td><strong>Ecophysiological correlates of plant mortality rates in a tropical forest</strong></td>
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<td>Louis Santiago. <em>University of California</em></td>
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<td>10:40-11:00</td>
<td><strong>Coffee Break</strong></td>
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<td>11:00</td>
<td><strong>Herbivory, ants, toxicity and secondary chemistry: divergence in the chemical ecology of</strong></td>
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<td><em>Inga</em> between two Neotropical Forest Dynamics Plots</td>
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<td>Tania Brenes. <em>University of Utah</em></td>
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<td>11:25</td>
<td><strong>Population dynamics of an Andean cloud forest: La Planada Forest Dynamics Plot</strong></td>
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<td>Martha Vallejo. <em>Instituto Alexander von Humboldt</em></td>
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<td>11:50</td>
<td><strong>Scaling of demographic rates and tree size distributions in tropical forests</strong></td>
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<td>Helene Muller-Landau. <em>University of Minnesota</em></td>
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<tr>
<td>12:15 p.m.</td>
<td><strong>Lunch</strong></td>
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<td>1:15 p.m.</td>
<td><strong>Poster session</strong></td>
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Sunday Afternoon, June 5th, 2005

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<tr>
<td>1:45 p.m.</td>
<td>Maximum likelihood estimation for neutral models in the presence of dispersal limitation</td>
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<td>Jerome Chave</td>
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<td><em>CNRS and Université Paul Sabatier Toulouse</em></td>
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<td>2:10 p.m.</td>
<td>The phylogenetic structure of tropical forest tree communities - new progress in data analysis</td>
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<td>Olivier Hardy</td>
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<td><em>Université Libre de Bruxelles</em></td>
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<td>2:35 p.m.</td>
<td>The role of immigrants in the assembly of the south America rainforest tree flora</td>
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<td>Christopher Dick</td>
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<td><em>Smithsonian Tropical Research Institute</em></td>
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<td>3:00 p.m.</td>
<td>Sex expression and microhabitat distributions of 16 species of dioecious Myristiaceae (nutmegs)</td>
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<td>in Amazonian Ecuador</td>
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<td>Simon Queenborough</td>
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<td>3:25 p.m.</td>
<td>Coffee Break</td>
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<td>3:50 p.m.</td>
<td>Tree diversity in montane evergreen forest of the Nilgiris Mountains, India</td>
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<td>Priya Davidar</td>
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<td><em>Pondicherry University</em></td>
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<td>4:15 p.m.</td>
<td>Vegetation dynamics in different habitats of the Mudumalai Wildlife Sanctuary –Southern India</td>
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<td>H.S. Dattaraja</td>
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<td><em>Indian Institute of Science</em></td>
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<td>4:40 p.m.</td>
<td>Phenology of tropical dry forest: the Nilgiris, Southern India</td>
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<td>H.S. Suresh</td>
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<td><em>Indian Institute of Science</em></td>
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<td>5:05 p.m.</td>
<td>Long-term phenology data from Barro Colorado Island, Panama.</td>
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<td>Joe Wright</td>
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<td><em>Smithsonian Tropical Research Institute</em></td>
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<td>6:00 pm</td>
<td>Reception</td>
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Poster Session

Seed rain and seedling establishment of tree species in a subtropical rainforest in Fushan, Northern Taiwan.
Chia-Ling Lu et al.

Impacts of long-term research on seedling dynamics in a permanent sample plot on Barro Colorado Island, Panama
Gregory R. Goldsmith et al.

Modeling spatio temporal populations of invasive plant species and their ecological impacts of forest sustainability at the Mundamalai Wildlife Sanctuary (India)
Yogesh D. Jadhav

Impact of heterogeneity of neighborhoods on long-term population dynamics of Acer saccharum, the dominant species in a temperate deciduous forest
Yiching Lin and Carol Auspurger

Abundant floral resources do not attract insects in deforested riparian corridors: the effect of deforestation on an endemic Amazonian herb
Christina D. McCain

Developments of a protocol to characterize soil drought stress for use in within- and among-site comparisons of CTFS plots
Chriss Mullins et al.

Forest Structure and diversity of a subtropical forest plot in Fushan, Taiwan
Sheng-Hsin Su and Chang-Fu Hsieh

Population and individual-level responses to hurricane disturbance: multiple mechanisms for successional diversity
Maria Uriarte et al.

Forest dynamics in a large plot of Yasuni National Park, Amazonian Ecuador
Renato Valencia et al.
ORAL PRESENTATION

ABSTRACTS

(In order of appearance)
The focus of CTFS research has so far been on understanding how tree species diversity is maintained in hyperdiverse forest communities. Only at Barro Colorado Island have dynamic data substantially contributed to this quest. Now though, the number of CTFS plots with at least three censuses is rapidly increasing. This provides opportunities for testing the replicability of BCI results, but also for describing and interpreting local and regional patterns of variation in structure and dynamics, and hence diversity.

Most forests, even in the equable humid tropics, are in process of recovery from catastrophic canopy opening and drought-induced juvenile mortality, whose spatial and temporal scale and intensity may vary predictably with climate and site. We now have the opportunity to monitor and compare disturbance events, although sometimes requiring additional sampling. This will throw light on factors affecting population and species maintenance and survival.

Such studies should redirect CTFS at last towards the highest research priority for most of our colleagues resident in the tropics: optimization of silvicultural management of forested landscapes for multiple benefits, which may include both timber and biodiversity conservation, especially where forests are fragmented and isolated by conversion.

The existence of an intercontinental network of CTFS plots, combined with some country-wide local networks of permanent small plots, provide other important opportunities for addressing theoretical issues through a comparative approach. Pressing questions in population genetics and phylogeography, in particular, can best be addressed while extensive tracts of forests yet remain in certain regions.
The role of mathematical theory in tropical forest ecology

Egbert Leigh

Mathematical theory of tropical forest ecology faces forbidding challenges. A tree's survival, growth, and reproductive capacity depends on the position, size, and competitive efficiency (ability to pre-empt light, water and nutrients and convert them into new trees) of its nearest neighbors. Thus a proper understanding of the dynamics and diversity of tropical forests requires knowing not only the number of trees in each specie, but the position, height, total area and spatial distribution of leaves and fine roots of these trees. A proper theory of leaf arrangement takes into account the leaves' capacity to intercept light as a function of the cost of supporting them and supplying them with water and nutrients. These tasks far exceed the ability of today's analytical theorists: only computer models like SORTIE can begin to cope with them.

Simpler theory, however, yields essential insight. Using Hubbell's neutral theory as a null hypothesis shows that to understand tree diversity, we must understand how different tree species coexist and resist competitive displacement by successful invaders. A crude analytical model of David King suggests how soil fertility affects gross production and its apportionment between above- and below-ground activities, explaining qualitative trends in wood production, tree mortality, wood density, and leaf lifetime from west to central and eastern Amazonia. Other theorists have related leaf lifetime to leaf toughness, photosynthetic capacity, stomatal conductance, crown form and wood density.

We are still left with the problem of extracting a comprehensive and communicable understanding from what seems a forbidding mass of detail.
Habitat associations around the globe


Habitat specialization may contribute to the maintenance of species diversity in communities of tropical trees and shrubs. Spatial distribution patterns resulting from habitat specialization should be distinguishable from patterns that would result from strict community drift and spatial random walks. We used spatially explicit statistical techniques to assess the distribution patterns of trees and shrubs greater than or equal to 1-cm dbh with respect to topographically defined habitats in a dozen permanent study plots. All of the study plots are larger than 16 ha, all are linked to the Center for Tropical Forest Science, and the plots collectively sample tropical forests of Asia, Africa, and the Americas. In all plots, 20 to 70 percent of species tested were non-randomly distributed with respect to topography. These levels of habitat association were consistently higher than expectations due to chance associations of species with topography, which were usually between 5 and 10 percent of species tested.
Long-term seed persistence facilitates species coexistence in tropical forests

James Dalling, Robert John-Chandran, and Thomas Brown

Shade-intolerant species, which constitute 10-20% of tree species in tropical forests, require canopy openings for successful regeneration. Four adaptive traits have been proposed to explain how these species colonize openings: prolific seed production, long-distance seed dispersal, disturbance-cued seed germination, and long-term seed persistence. Relationships among the first three of these traits are well described, and show that trade-offs among traits favoring dispersal and post-dispersal establishment can mediate coexistence among species that vary over five orders of magnitude in seed mass. However, the potential contribution to recruitment from long-persistent seeds in the soil seed bank has been overlooked, in part because demographic studies of common, small-seeded pioneers have shown their seeds persist for a few years or less. Here we use a carbon-dating approach to provide the first direct evidence that the scale of seed persistence for pioneers is decades rather than years. We then explore the implications of long-term persistence for recruitment and coexistence, and use simulations to examine whether seed persistence can compensate for limited seed dispersal.
Effects of soil-borne resources on tree distributions in three Neotropical forest plots


In principle, niche differentiation with respect to soil-borne resources can account for the high diversity of tree species in tropical forests. In practice, however, such specialization among tree species has been difficult to quantify, primarily because the distributions of tree species and of soil-borne resources are poorly known. Here we present data from three diverse Neotropical forest plots in Colombia (La Planada), Ecuador (Yasuni), and Panama (BCI), for which tree distributions and soil nutrient concentrations have been mapped in detail. At all three sites, previous studies had found non-random associations of tree species to topographical features but the underlying resource gradients had not been mapped. We found that the three sites differ considerably in soil nutrient distributions and soil fertility. Soil phosphorus level is low on BCI (mean=2.8 mg/kg) and Yasuni (4.8 mg/kg) but far higher in La Planada (23 mg/kg). Calcium (1684 mg/kg) and magnesium (290 mg/kg) are relatively abundant on BCI, but low in Yasuni (Ca=385 mg/kg, Mg=99 mg/kg) and La Planada (Ca=212 mg/kg, Mg=28 mg/kg), while aluminum shows the reverse distribution with the highest value at La Planada (3716 mg/kg), a lower value at Yasuni (1791 mg/kg) and the least at BCI (1013 mg/kg). Moreover, the three sites also differ with respect to the correlations between soil nutrients and topographical features such as slope, elevation and convexity. These correlations were generally weak, but were strongest for BCI, weaker in Yasuni and very poor in La Planada. We reexamine previously reported topographical habitat associations using these new data on soil nutrient distributions. We apply ad hoc tests such as the torus test and the Poisson cluster model test since they have been previously used, but also develop new parametric approaches using spatial point process models to test soil nutrient-species associations.
Seasonal variation in irradiance is a dominant influence on tropical flowering and fruiting phenologies

Jess K. Zimmerman and S. Joseph Wright

Ecologists have long assumed that the key climatic determinant of community-wide seasonal flowering and fruiting in tropical forests is rainfall. Analyzing trapfall data collected in two forest dynamics plots with contrasting annual rainfall patterns, we provide evidence that seasonal changes in irradiance may be the critical determinant of tropical phenologies. Beginning with an everwet site (Luquillo; 10 years of trapfall data) where monthly average rainfall is never less than 200 mm and seasonal variation in irradiance is largely determined by daily maximum sun angle, we show that there is a significant tendency for trees and shrubs to avoid reproduction in the winter solstice when irradiance levels are lowest. We then turn to a seasonally dry site (Barro Colorado Island; 4 month dry season; 15 years data) where flowering and fruit production are expected to be timed to take advantage of the onset of seasonal rains. We find again, however, that community-wide peaks in flowering and fruiting are best explained by seasonal changes in irradiance and not rainfall. The finding that seed dispersal is not closely timed to the onset of seasonal rains at BCI may seem surprising until one considers that many species possess dormancy mechanisms that ensure that seed germination occurs near the onset of rains. We then compare eight species which are common in both sites to test the idea that phenologies of individual species may represent local adaptation (phenologies of individual species are adapted to local climatic conditions and, therefore, differ between sites) or an ecological filter (species with maladaptive phenologies are excluded from one site or the other and, therefore, species common to both sites have similar phenologies). Evidence for an ecological filter was found in four of eight species but the remaining species did not conform to either model.
Ecosystem decay of Amazonian forest fragments

William F. Laurance

I will synthesize key findings from the Biological Dynamics of Forest Fragments Project (BDFFP), the world’s largest and longest-running experimental study of habitat fragmentation. My main focus will be on the effects of fragmentation and edge effects on complex Amazonian tree and liana communities.

Forest fragmentation leads to rapid changes in tree communities, mainly as a result of edge effects. Near fragment margins, wind turbulence and desiccation stress increase markedly, leading to a sharp increase in tree mortality and damage. This results in a “collapse” of live tree biomass as large, long-lived trees die at the expense of smaller, shorter-lived successional trees and lianas. Tree-community composition evidently changes quite rapidly; pioneer species such as *Cecropia sciadophylla*, for example, increase by >3000% during the first two decades after fragmentation.

Although initially designed to assess the influence of fragment area on Amazonian biotas, the BDFFP has yielded insights that go far beyond the original scope of the study. Results suggest that edge effects play a key role in fragment dynamics, that the matrix has a major influence on fragment connectivity and functioning, and that many Amazonian wildlife species avoid even small (<100 m wide) clearings. The effects of fragmentation are highly eclectic, altering species richness and abundances, species invasions, forest dynamics, the trophic structure of communities, and a variety of ecological and ecosystem processes. Moreover, forest fragmentation appears to interact synergistically with ecological changes such as hunting, fires, and logging, collectively posing an even greater threat to the rainforest biota.
Density-dependent growth of established seedlings in the Barro Colorado Island 50-ha plot

Liza S. Comita and Stephen P. Hubbell

The Janzen-Connell hypothesis posits that species coexistence in tropical forests is fostered by host-specific natural enemies, such as seed predators, herbivores and pathogens, which cue in on areas of high conspecific seed and seedling densities close to parent trees. As a result, seeds and seedlings at high conspecific densities have lowered rates of survival and growth. In the Barro Colorado Island tree community, negative density dependence during the seedling establishment phase is widespread. However, once established, seedlings can spend decades in the shaded understory, and the prevalence of density dependence in the Barro Colorado Island forest during this life stage is not known. Since 2001, we have monitored the annual growth and survival of established seedlings and small saplings (>20cm in height and <1cm DBH) in twenty thousand 1-m² seedling plots located throughout the 50-ha plot on Barro Colorado. Using these data, we examine patterns of established seedling growth as a function of neighborhood seedling and tree density and discuss the role of density dependence in the maintenance of diversity in the Barro Colorado Island tree community.
A comparison of seedling dynamics among three CTFS sites

Margaret Metz, Liza Comita, and Yu-Yun Chen

Many of the ecological mechanisms hypothesized to maintain the diversity of tropical forests focus on processes occurring during the seed and seedling life history stages. Seedling studies underway in the plots at Barro Colorado Island (Panama), Pasoh (Malaysia) and Yasuní (Ecuador) make it possible to determine whether patterns predicted by these hypothesized mechanisms fit what we see in the field. We examine data on seedling recruitment, growth, and mortality to determine whether these rates vary with topography or light availability, as expected from hypotheses of habitat specialization. Alternatively, these rates may vary with an individual’s distance to the nearest conspecific adult or density of conspecific seedlings, as predicted by the Janzen-Connell model. More simply, seedling dynamics may purely be determined by the quantity and composition of local seed rain. Because we employ identical methodology at the three sites, we can also test whether the factors driving seedling dynamics are similar in tropical forests worldwide. This comparison is particularly interesting because the forests differ in a number of important aspects including species richness, seasonality and biogeography. The results of our preliminary comparisons reveal interesting differences in seedling dynamics among the three sites and provide incentive for further exploration. We are continuing this investigation by developing models of seedling recruitment, growth, and mortality to examine how the local biotic neighborhood and physical environment drive seedling dynamics and shape the eventual composition of the adult forest. Here, we present our initial findings from basic comparisons of seedling dynamics among three study sites and preliminary insights from models of seedling dynamics.
“Hasta los palos del monte…”: spatial distribution and seedling success in three Nicaraguan rainforest trees

Douglas H. Boucher, Javier E. Ruíz, Cherryl Ingram, and Karla Sequeira

We studied the population dynamics of three species of Nicaraguan trees at two lowland rain forest sites, gridded on a 10 x 10 m scale and totalling 12 ha, since 2002. We mapped the distribution of over 10,000 individuals each year, relating growth and survival rates of seedlings to their location and environmental variables, including soil type, topography, and distance to conspecifics.

There is evidence for Janzen-Connell effects on both survival and growth in all three species. Dispersal limitation is acute in the animal-dispersed palm *Welfia regia* but weak in the animal-dispersed legume *Dipteryx oleifera*, with the wind-dispersed *Vochysia ferruginea* intermediate. Secondary dispersal by terrestrial rodents, after primary dispersal by bats, is key to reducing dispersal limitation in *Dipteryx*.

The seedling shadow of the wind-dispersed *Vochysia* is elliptical rather than circular, and is not centered on the parent tree but rather to the west of it. The seedling shadows of the two animal-dispersed species are considerably more irregular. So far, conspecific neighborhoods seem more important to seedling success than soil and topography.
Modeling gap regeneration in tropical forests

Toby R. Marthews, Christopher E. Mullins, David F.R.P. Burslem, and A.J.S. McDonald

Understanding the mechanisms that maintain tropical tree species diversity through space and time would be greatly advanced if it were possible to model even a small part of the dynamics of a tropical forest. Given the importance of gaps in such forests, we have constructed a spatially-explicit, individual-based model of the life cycles of three pioneer tree species in the neotropical lowland forest of Barro Colorado Island, Panama. Our model concentrates on the early parts of the life cycle, modeling four life stages: (1) dispersal and seed arrival on the forest floor, (2) post-dispersal seed burial and mortality, (3) seed dormancy germination and emergence, and (4) the seedling/adult stage. Our model assumes that, apart from sunlight and rainfall, all processes that maintain tree biodiversity are internal to the forest. Preliminary simulations of the environmental submodel show that even cleared gaps contain a wide range of microsite conditions. Depending on the time of year, some portions of the gap may be in continual shade whilst others are receiving up to 6 hours direct sunlight. Measurements taken in a 20 m² gap on BCI in 2003 confirm that some seeds in gaps experience understory conditions whilst seeds a few meters away may experience temperatures over 40 ºC. We propose to validate the completed model by comparison with gap composition in the large-scale forest dynamics plot on Barro Colorado.
Pulliam effects and size-related diversity changes in a lowland tropical rainforest

Matthew D. Potts, Stuart J. Davies, and Sylvester Tan

Niche-based theories posit that species coexist through habitat specialization. Few studies have looked at species habitat preferences for a large number of species in tropical rainforests, and even fewer studies have tried to link the patterns of species habitat preference to process. In this study, we have done both. Drawing upon data from a Bornean tropical rainforest, we assessed the degree of habitat specialization. We also tried to distinguish whether small-scale patterns of small tree species diversity were being driven by source-sink dynamics (Pulliam effects). We tested this hypothesis using a combination of geostatistical and point-based spatial statistical techniques along with multinomial logistic regression. Our findings provide strong evidence of habitat specialization, with 75% of the species exhibiting some degree of specialization. In addition, the pattern of small-scale species diversity was consistent with the Pulliam hypothesis, with the most diverse areas being made up of a high proportion of individuals of different habitat types. We place our results in a comparative context with respect to other studies of habitat specialization in tropical rainforests.
Genetic evidence that successful long distance seedling recruitment is commonplace in a vertebrate-dispersed Neotropical tree

Britta Denise Hardesty, Stephen Hubbell, and Eldredge Bermingham

We used microsatellite genetic markers to match seedlings to their maternal and paternal parents in a population of the dioecious Neotropical tree, Simarouba amara (Simaroubaceae) in the Barro Colorado Island 50-ha plot in Panama. Our main objectives were to: 1) measure dispersal distance of successful seedling recruits and 2) to compare gene movement via seed and pollen. Our definition of recruitment includes seed dispersal, germination and subsequent seeding establishment. Long distance dispersal was frequent in Simarouba: 74% of seedlings were dispersed > 100 m, and fewer than 10% of seedlings were produced by the nearest reproductive female. The mean dispersal distance between established seedlings and their maternal parent was 348 m (range 9.3-100.5 m), and the mean distance between half and full siblings was 215.8 m (range = 0.81-801.6 m, median 187.4). Sib distances were significantly greater (P < 0.0001, T-test) than nearest seedling distances (mean distance to nearest seedling neighbor, 11.3 m, median 6.2 m). Gene movement via pollen was comparable to that of seed, averaging 373.2 m (range 1.4-1005.8 m). Our findings demonstrate that most seedlings recruiting in this species are dispersed well beyond the crown of the parent tree, probably by birds or primates.
Seasonal and interannual canopy changes on Barro Colorado Island derived from remote sensing

Stephanie Bohlman

On the Barro Colorado Island 50-ha plot, I used a variety of remote sensing techniques to gather information about the forest canopy which complements traditional, ground-based measurements. Color aerial photography taken at different times of the year can identify trees that are in fruit or flower. From this, I can determine synchrony among individuals on a large spatial scale, and potentially quantify reproductive output. Also, species with copious flower and fruit production at the top of their crowns, or with unique non-reproductive crown form, can be mapped, providing species distributions beyond the 50-ha plot. For example, I mapped palms and *Jacaranda copaia* over the whole island. Images taken at multi-year time intervals can provide estimates of crown growth, breakage, mortality, and “recruitment” into the canopy. From 2000-2005, I quantified the number of canopy trees that died in 9-ha of the plot and tested whether depressed growth rate and exposed crown area provided an indicator of mortality risk. Aerial surveys can provide a non-intrusive method to provide greater temporal resolution and wider spatial coverage of forest dynamics than stem-based measurements.
Assessment of soil-water interactions at the plot scale in tropical landscapes

Robert F. Stallard

Hydrologic processes in tropical landscapes control much of the interaction between plants, water, soils, and nutrients. Soil permeability on a micro and macro scale determines whether water and nutrients filter into the soil and interact with roots or flow above the soil and bypass terrestrial plants.

The network of large-scale forest plots under the umbrella of the Center for Tropical Forest Science span a wide range of soil types and therefore hydrologic interactions. Some critical types of interactions are under-represented, though, such as soils with highly developed root mats. The thick root mat is an excellent example of a community-scale adaptation whereby plants strongly control the hydrology of the interaction between water, nutrients, and plants in a way that is strongly beneficial to plants.

Standardized examination of the interactions between soils and water are underway at several CTFS plots. Each study is finished in two to four weeks, and such a limited duration requires a streamlined approach including both fieldwork and modeling. The fieldwork involves measuring soil permeability, gauging streams, measuring rainfall, and monitoring the pattern and distribution of runoff. Subsequently, simple hydrologic models will be implemented at each plot. Input data for the models includes site-scale and regional data, and important model constraints are stream and rainfall chemistry. These constraints, in turn, can be used to address the interaction between nutrients, hydrology, and soils, further refining the information needed to assess the distribution of trees.
Species drought resistance shapes local and regional species distribution patterns in tropical forests

Bettina M. J. Engelbrecht, Liza S. Comita, Richard Condit, Thomas A. Kursar, Melvin T. Tyree, and Stephen P. Hubbell

Tropical forests possess the most diverse plant communities on earth, yet the processes dictating tropical species distributions, and thus community composition and diversity, remain poorly understood. The most pervasive patterns of species distributions in tropical forests worldwide, as well as in many non-tropical systems, are regional and continental scale correlations with rainfall, and local scale associations with topographically defined units, which frequently vary in soil water availability. However, factors that co-vary with water availability, namely herbivore and pathogen pressure, and light and nutrient availability, have also been proposed to produce these patterns. Efforts to distinguish between these potential factors have been hampered by a lack of comparative experimental data on tropical plant species’ reactions to relevant axes of environmental variation. Here we use experimental field assessments of drought resistance of 48 native tree and shrub species to show that differential drought resistance shapes both local species distribution in the 50-ha forest dynamics plot on Barro Colorado Island, and regional species distributions across a rainfall gradient spanning the Isthmus of Panama, assessed in a network of 67 forest plots. Our results suggest that niche differentiation with respect to water availability is an important determinant of local and regional distributions in tropical forests. Changes in soil moisture availability mediated through global climate change or forest fragmentation are therefore expected to have a strong impact on species distribution, community diversity and ecosystem function.
Leaf hyperspectral optical scans for rapid tree ecophysiological surveys: comparative results from three CTFS sites

Sean C. Thomas

Tackling complex systems with immense sample sizes is the essence of the CTFS research strategy; however, basic ecophysiological data is presently available for only ~80 species in selected taxa across the CTFS plots. There is thus little capacity at present to make use of the large sample sizes of species represented by the CTFS plot data in conjunction with ecophysiological information. I investigated the potential for using rapid hyperspectral optical scans of leaves as a method for broad-scale ecophysiological surveys at CTFS plot sites. Leaf optical surveys were made for a range of species at Barro Colorado Island Panama, Pasoh Forest Reserve Malaysia, and a new temperate forest site at Changbaishan, NE China. A purpose-built spectroradiometer configured with a dual-integrating spherical sampling port was used to collect leaf reflectance and transmittance spectra in the 400-1000 nm waveband at a ~0.3 nm resolution: a single scan with this instrument requires <10 seconds. Spectral indices were used as proxy-measures for leaf chlorophyll, carotenoid, and anthocyanin pigment content, and mesophyll cell surface area. In addition, leaf reflectance and transmittance spectra were empirically related to direct measurements of both ecophysiological parameters (e.g., photosynthetic capacity, leaf mass per area, leaf thickness), and ecological attributes (e.g., successional status, growth, mortality). The results document pronounced species differences in leaf optical characteristics that include systematic differences among ecological groups. Adaxial reflectance parameters alone showed relatively weak correlations with other tree characteristics. However, inclusion of transmittance and abaxial reflectance data improved empirical predictions of photosynthetic and ecological parameters, with abaxial/adaxial differences generally being more pronounced in rapidly-growing early successional species. In conclusion, leaf hyperspectral scans offer considerable promise for large-scale ecophysiological surveys at both accessible and remote tropical sites, and provide a new technical tool to rapidly assess aspects of the functional biology of tropical trees at CTFS sites to complement the "core" CTFS data on tree densities, growth, and mortality.
Ecophysiological correlates of plant mortality rates in a tropical forest

Louis S. Santiago

In tropical forest plants, mortality is determined by physiological tradeoffs that reflect how resources are allocated to competing functions. I evaluated these tradeoffs for plants in tropical moist forest at Fort Sherman, Panama. Five bivariate relationships relating mortality to wood density, hydraulic conductivity, photosynthesis, leaf lifespan, and specific leaf area, were evaluated. Wood density showed a negative relationship with mortality, suggesting that dense wood confers resistance to physical stress. On the other hand, a positive relationship between mortality and hydraulic conductivity ($p < 0.15$) suggests that dense wood may restrict vessel size and thus water transport. Mortality also showed a positive relationship with mass-based maximum photosynthetic rate, suggesting a mechanism for the previously observed positive relationship between mortality and growth. Mortality was positively related to specific leaf area and negatively related to leaf lifespan. These results indicate that a suite of leaf traits relating to potential growth are constrained by wood density. I propose that four interrelated traits – wood density, hydraulic conductivity, photosynthetic rate, and mortality – define the major axis of trait variation in tropical forest trees. These mechanisms underpin the growth strategies of tropical plants and have implications for the persistence of species in tropical forest communities.
Herbivory, ants, toxicity and secondary chemistry: divergence in the chemical ecology of *Inga* between two Neotropical Forest Dynamics Plots

Tania Brenes-Arguedas, Phyllis D. Coley, and Thomas Kursar

The study of plant chemical ecology in species rich communities is a difficult challenge due to the large number of interacting organisms. Some of the original coevolution models assumed interactions were between one plant and one specialist herbivore. However, in natural ecosystems these interactions are rarely exclusive, and may vary widely among populations due to species turnover. This study provides a two-site comparison of plant chemical ecology in two CTFS plots with different species compositions, Yasuni in Ecuador and Barro Colorado Island (BCI) in Panama. We focused on the genus *Inga* (Mimosoidae), an abundant Neotropical legume that appears to be speciating rapidly. *Inga* is defended by flavanoids, saponins and ants, which are attracted to extra-floral nectaries. The Yasuni Plot has 3 times as many *Inga* species as BCI and *Inga* trees are almost 4 times as abundant. We studied 14 species, six of which are found in both plots. Within a site, *Inga* species share many of their herbivores with other congeners, suggesting that plant-animal interactions are interconnected. Reciprocal transplant experiments suggest that *Inga* at Yasuni experiences nearly 3 times the herbivore pressure as BCI. However, the average rate of herbivory observed in naturally growing plants is not different between the sites. This is partially explained by differences in ant visitation. In Yasuni, young *Inga* leaves are visited by ants 50% more often than at BCI, with the most common ants being group foragers. *Inga* chemical defenses should be influenced by this interaction between herbivore pressure and ant abundance. In fact, for some species that occur at both sites there is divergence in secondary chemistry and toxicity. Our results are consistent with a model in which differences in the interactions of *Inga* with herbivores and distinct selective pressures on chemical defenses could be key drivers of genetic divergence among *Inga* populations.
Population dynamics of an Andean cloud forest:  
La Planada Forest Dynamics Plot

Martha Isabel Vallejo and Cristián Samper K.

We studied the growth, mortality and recruitment dynamics of an Andean cloud forest at La Planada Nature Reserve in Colombia. A total of 113,181 ligneous stems (dbh ≥ 1 cm) were measured in 1997, with a second census in 2002. The results show an annual mortality rate of 0.036 and a slightly lower annual recruitment rate of 0.035 over 5.6 years, which generate a negative rate of population change of -0.0178. The species with greater positive population change (>10 % increase in number of stems) were Wettinia kalbregery (Arecaceae), Siparuna sp.2 (Monimiaceae) and Myrcia sp.3 (Myrtaceae), and those with the larger negative population change (>10 % decrease in number of stems) were Alloplectus schultzei (Gesneriaceae) and Alchornea sp.1 (Euphorbiaceae). The annual average growth rate was 1.41 mm. However, some fast growing species like Merania spp. (Melastomataceae), Brunellia sp. (Bruneliaceae), Cordia spp. (Boraginaceae) and Cecropia monostachya (Cecropiaceae) had average growth rates of up to 12 mm per year. The largest growth rates were found for stems with diameters between 175 to 500 mm, where average growth rates were > 3 mm per year. This is similar to growth rates from lowland forests. These are the first findings from a large-scale plot in Andean cloud forest; they suggest that cloud forests have higher mortality rates and faster population dynamics than lowland forests, despite the absence of large-scale disturbances.
Scaling of demographic rates and tree size distributions in tropical forests


Tree growth rates, mortality rates, and size distributions vary considerably among tropical forests, yet exhibit certain regularities that suggest the influence of fundamental constraints. In recent years, metabolic ecology theory has produced predictions for the form of tree size distributions and demographic rates. In particular, Enquist et al. 1999 propose that diameter growth rates scale as the 1/3 power of diameter, and Enquist & Niklas 2001 propose that tree size distributions scale as the -2 power of diameter. We show that these two predictions in turn imply that mortality rates should scale as the 2/3 power of diameter. We use data from 12 CTFS plots to test these three predictions. Diameter growth rates do scale approximately as a power function of diameter, but the exponents in closed canopy forests are close to 2/3, not the predicted 1/3. Mortality rates scale less consistently, and their best power-function fits in closed forests have exponents of less than 1/3, rather than the predicted 2/3. Tree size distributions in closed-canopy forests scale approximately as the -2 power of diameter for trees less than 40 cm dbh, but show much steeper and less consistent slopes at higher diameters. Thus, the data for the most part do not support the predictions of metabolic ecology theory. We present an alternative derivation of the scaling of growth rate with size based on the allometric scaling of light interception with size and the empirical relationship between light availability and height within the forest. We parameterize this model with allometric and canopy data from BCI. The resulting predictions closely match the scaling of growth with diameter in this forest. We discuss the implications for understanding site differences in tree demographic rates and size distributions, and hence in tree density, total biomass, and carbon stores and fluxes.
Maximum likelihood estimation for neutral models in the presence of dispersal limitation

Jerome Chave

Validating models with field data remains a great challenge in ecology. The neutral theory of biodiversity has often been tested by comparing empirical data on species abundance to the model's predictions either visually, or using inappropriate statistical tools (e.g. chi-square tests). Statistically sound techniques have been published recently (Alonso and McKane 2004, Etienne and Olff 2004). These works suggest procedures to estimate the quality of the neutral model by a maximum likelihood (ML) approach, following the method suggested long ago by Warren J Ewens (Ewens 1972). Importantly, Etienne (2005) generalized this ML estimation to a neutral model in the presence of dispersal limitation. Here I present (1) a fast numerical model for performing Etienne's ML estimation given species abundance data, (2) a test of this ML estimation using simulated data, and (3) preliminary results of the ML estimation on real datasets. In some cases dispersal limitation can indeed be detected from species abundance curves. Finally, I discuss the biological implications of these results.
The phylogenetic structure of tropical forest tree communities - new progress in data analysis

Olivier J. Hardy and Bruno Senterre

Because species life-history traits tend to be mostly conserved during speciation events, the degree of niche differentiation between species is expected to be positively correlated with their phylogenetic distance. Therefore, investigating species assemblages in a phylogenetic perspective can provide clues about the impact of non-neutral processes in structuring communities (niche assembly). A new theoretical framework is developed to characterize the phylogenetic structure of communities using diversity coefficients that take species phylogeny into account. By partitioning these coefficients within and among plots and applying a phylogenetic randomization procedure, it is possible to test whether co-occurring species are more related than expected from a neutral model. Using a recently published dated super-tree of Angiosperm families, the method is applied to tropical forest tree inventories. It shows evidence that the strength of the phylogenetic signal is correlated with the ecological differentiation between plots, demonstrating the impact of niche differentiation and ecological sorting. Partial randomizations of the phylogenetic tree are also used to investigate whether different clades contribute equally to the phylogenetic signal.
The role of immigrants in the assembly of the South America rainforest tree flora

Christopher Dick, Consuelo Hernández Rentería, Toby Pennington, and Renato Valencia

The Amazon lowland rain forest flora is typically thought to comprise lineages that originated before the split of west Gondwana (c. 100 Ma). Recent molecular phylogenies, however, identify immigrant lineages that arrived in South America before the closure of the Panama Isthmus (c. 3 Ma) and long after fragmentation of Gondwana. We present evidence from fossil-calibrated phylogenies and biogeography that demonstrate a strong influence of immigrant lineages on the tree diversity of South American rainforests. An analysis of inventory plot data from Yasuní, Ecuador, suggests that immigrant lineages comprise c. 20% of both the tree species and individual stems found in a 25-ha Amazon forest plot. This is more than an order of magnitude higher than previous estimates. Our results are consistent with a growing body of evidence from molecular systematics suggesting that long distance dispersal is the primary explanation for floristic similarities between neotropical and palaeotropical forests, rather than a shared Gondwanan history.
Sex expression and microhabitat distributions of 16 species of dioecious Myristicaceae (nutmegs) in Amazonian Ecuador


Two censuses of flowering individuals of the dioecious tree family Myristicaceae on the Yasuni 50-ha Forest Dynamics Plot in Yasuní National Park, Amazonian Ecuador, have revealed differences in patterns of sex expression in the family. Sex ratios (male/male+female) varied from 0.29 to 0.75 and were significantly male-biased in four species in at least one year. For the family as a whole the sex ratio was male-biased. This male bias was due to precocial male flowering in most species, rather than more frequent male flowering or higher female mortality. There were no differences between male and female growth rates.

The sexes of four of eight species tested had clumped distributions using Ripley’s K analysis. Although there was no reciprocal spatial segregation of the sexes, females showed significant habitat associations in 75% of species tested using a torus translation procedure, while in only 25% of species did males show a habitat association.

These results support the general finding of male-biased sex ratios in tropical tree species, explain the likely reason for its occurrence at Yasuní, and provide the first spatial autocorrelation analysis of distributions of the sexes in a dioecious tree.
Tree diversity of montane evergreen forests of the Nilgiri Mountains, India

Priya Davidar and D. Mohandass

Shola forests of the upper plateau (> 2000 msl) of the Nilgiri Mountains are discrete evergreen forests in the hollows and valleys of the mountains, separated by grasslands. Tree diversity in 20 small and large sholas comprising a total area of 12.58 ha were sampled in randomly placed 30 x 30 m plots. All trees ≥ 1 cm dbh were inventoried. Species richness increased with shola area, and Fisher’s diversity index alpha ranged from 6 to 11. Species distribution patterns were strongly nested, and similarity of species composition between sholas did not decrease significantly with distance. Widespread common species and habitat generalists dominated the assemblage. Historical climate change and a long dry season probably account for the observed patterns.
Vegetation dynamics in different habitats of the Mudumalai Wildlife Sanctuary – Southern India

H.S. Dattaraja, H.S. Suresh, and R. Sukumar

Nineteen one ha permanent plots were established in 1994-1995 along a moisture gradient in the Mudumalai Wildlife Sanctuary to provide additional information for the large 50-ha plot established in 1987-1988. The 1-ha plots were recensused in 1998-1999 and 2003. The plots were monitored for changes in growth, mortality and recruitment. In general, the smaller girth-class trees tended to have higher mortality rates compared to larger trees in all the habitats. We observed recruitment as low as 0% in the highly degraded dry thorn forest with lowest rainfall, and as high as 14.7% in moist deciduous habitat with moderate rainfall. Mortality was highest among moist forests compared to dry forests, ranging from 5.31% to 43.31%. The mean annual growth rate was significantly different among size-classes, but no significant difference among forest types was found. Annual recruitment and mortality seemed to increase with increase in mean annual rainfall. Mortality and recruitment patterns reveal differences among the vegetation types. Slope and microhabitat, fire, and human disturbances are probably the major factors contributing to differences in population dynamics.
Phenology of tropical dry forest: the Nilgiris, Southern India

H. S. Suresh and R. Sukumar

Foliar and reproductive phenologies of dry forests in the Nilgiris Hills, Southern India, were monitored. A total of 329 individuals belonging to 52 species in a dry deciduous forest and 226 individuals of 44 species in a tropical dry thorn forest were monitored for foliar and reproductive phenology. The phenophases studied were leaf initiation, expansion, and senescence, flower initiation, bud break, and maturity, and fruit initiation, development, and abscission. Phenology has been recorded every month since August 2000. Herbivory rates were collected, and climatic data were assembled from the weather stations maintained by the Center for Ecological Sciences. Data were analyzed for influence of climate on phenology. Seasonality, as well as differences in the phenology of life forms, was also analyzed. The phenology of two different forests was compared. Finally, the observed pattern of phenology was discussed in the light of current theories and patterns observed elsewhere in the tropics.
POSTER PRESENTATION

ABSTRACTS

(In alphabetical order)
Seed rain and seedling establishment of tree species in a subtropical rainforest in Fushan, Northern Taiwan

Chia-Ling Lu, Chia-Hao Chang-Yang, and Chang-Fu Hsieh

For the purpose of studying seed rain and seedling establishment of tree species, we set up 87 stations in the 25-ha Fushan plot using the protocol established in the 50-ha plot on Barro Colorado Island, Panama. The objectives of this study are to understand the temporal variation of the seed rain and the seedling density of tree species, and the relationship between seed rain and seedling bank. We describe the regeneration strategies of the main tree species in the Fushan plot.

In this study, all seeds, fruits, and fruit fragments > 1 mm in diameter falling into the traps were counted and identified to species each week from Sept. 2002 to Mar. 2004. In Sept. 2002, all tree seedlings < 1 cm DBH in the 261 seedling plots were tagged and identified to species. Survivors were re-measured and new recruits were tagged and identified every three months from Feb. 2003 to Feb. 2004.

There were 9,580 seeds collected from 87 seed traps, belonging to 23 tree species. During 2003, the species with the most fruits was *Limlia uraiana*, followed by *Castanopsis carlesii*, but a large proportion of fruits were immature. The species with the highest ratio of mature to immature fruits was *Lagerstroemia subcostata*, followed by *Glochidion acuminatum*. Seed viability percentages were quite different among main species, ranging from 26% to 99%.

A total of 4,794 new seedlings were found, belonging to 18 species. There were 15 species from which both seeds and seedlings were recorded. New seedlings were found in each re-census. The highest density of seedlings occurred in May 2003, and the highest number of species occurred in Aug. 2003. Most species had low seed-to-seedling transition probabilities (mean seedling density / mean seed density). Five species with a seed mass of less than 8 mg accounted for 73.4% of the seed rain but just 3.8% of the recruits in Feb. 2004. The species with smaller seeds, smaller seedlings, and epigeal germination had the highest seedling mortality.

Regeneration strategies varied substantially among tree species. *Schefflera octophylla* and *G. acuminatum* produced many seeds to ensure enough recruits. *Machilus thunbergii*, *Machilus zuihoensis*, and *Litsea acuminata* produced better quality seeds and had higher seedling survival rates. *L. uraiana* and *C. carlesii* had few seeds and seedlings, and their regeneration probably relied on sprouting.
Impacts of long-term research on seedling dynamics in a permanent sample plot on Barro Colorado Island, Panama

Gregory R. Goldsmith, Liza S. Comita, Leslie L. Morefield, and Stephen P. Hubbell

Permanent sample plots have become cornerstones for the measurement of forest dynamics worldwide. A pitfall may be, however, that the large-scale research effort necessary to quantify ecological processes may alter the forest. Our study sought to quantify the impact of trampling caused by a seedling census within the 50-ha plot on Barro Colorado Island, Panama. We compared 20,000 seedling plots inside the 50 hectares, established in 2001, with 600 newly established seedling plots in an area of reduced research just outside the plot, testing for differences in seedling density and dispersion, size-class distribution, species richness, evenness, and overall composition. Seedling density, diversity and composition did not differ significantly inside and outside the 50-ha plot, and we conclude that trampling by researchers does not affect seedling dynamics. Further efforts should be made, though, to test for subtle or long-term changes caused by the research effort.
Modeling spatio temporal populations of invasive plant species and their ecological impacts on forest sustainability at the Mundamalai Wildlife Sanctuary (India)

Yogesh D. Jadhav

Invasive plant species have been known to cause massive damage to agricultural and forestry sectors in India. Due to anthropogenic disturbances and ecosystem fragmentation, invasive species find an easy ‘inlet’ into protected areas and forests. These species (commonly called ‘weeds’) can drastically decrease tree growth. They proliferate on any available land and compete with naturally-occurring seedlings for space, nutrients and sunlight.

The reasons for the prolific spread of invasive species are the aggressive modes of their propagation and specialized physiological adaptions, rendering them resilient and competitive. In order to achieve sustainable management of tree resources in natural forests, it is mandatory to assess the populations of weed species, periodically monitoring their ecological impacts.

The present phase of the project (a pilot study of 3 months) is an attempt to map the distribution of invasive plants in the forest dynamics plot at Mudumalai wildlife sanctuary in India. Over the next 18 months, the ecological impacts of invasive plants on tree species will be examined and possibilities for weed control will be explored.
Impact of spatial heterogeneity of neighborhoods on long-term population dynamics of *Acer saccharum*, the dominant species in a temperate deciduous forest

Yiching Lin and Carol K. Augspurger

One of main objectives of ecology is to understand how to link processes at one spatial scale to patterns at larger scales. We used neighbor-specific transition matrices to evaluate effects of spatial heterogeneity at the scale of individual trees on long-term population dynamics of *Acer saccharum* in an old-growth forest in Illinois. All trees with diameter at breast height (DBH) ≥ 7.6 cm in eight discrete quadrats (48 x 68 m) and one large quadrat (216 x 260 m) were mapped in 1951, 1988, and 2001. Five neighbor-specific transition matrices were constructed and integrated into one megamatrix for each of the two census periods (1951-1988 and 1988-2001). Computer simulations were used to evaluate effects of the relative proportion of different neighborhoods on population dynamics. Our results indicate that different neighborhoods and their relative proportion resulted in major differences in subsequent demography and population dynamics of *A. saccharum*. Megamatrices projected faster population growth than did non-spatial matrices. This study indicated that population dynamics of *A. saccharum* was driven by disturbance-facilitated recruitment. Using matrix modeling, we demonstrated that small differences at the scale of individual trees were sufficient to cause substantial differences in the dynamics at the scale of tree populations.
Abundant floral resources do not attract insects in deforested riparian corridors: the effect of deforestation on an endemic Amazonian herb

Christina D. McCain

Riparian habitats are known to be important to regional species diversity and forest ecosystems in Amazonia, and their conservation is specifically mandated by Brazilian law, yet little research has targeted this habitat. I studied the impact of deforestation of surrounding terra firme on the abundant riparian herb, *Rapatea ulei* (Rapateaceae), and its associated insects. *R. ulei* provides a reliable and abundant resource for euglossine bees and an impressive diversity of other insects, and so is likely to be important to riparian insect food webs where it occurs. Populations of *R. ulei* in intact forest were compared with populations in forest corridors among pasturelands. Flower production, plant density, floral visitors, and female reproductive success were compared among six populations. Reproductive plants were 3.5 times more abundant in deforested sites than in intact forests, reaching densities of over 800 flowering plants/plot, compared to 91 flowering plants/plot in intact forest. Though density differed drastically among habitats, there was no significant difference in flower production per plant. In contrast, seed production was significantly lower in deforested than in intact sites. Populations with the lowest densities of flowering plants had the highest seed production/plant. In low-density intact forest populations, greater than 20% of ovules resulted in mature seeds, compared to 1% – 5% in deforested sites. Pollinators paid 75% fewer visits to flowers in deforested areas, and herbivorous insects were also less common there. This study demonstrates that dense flowering populations do not necessarily indicate reproductive success.
Development of a protocol to characterize soil drought stress for use in within- and among-site comparisons of the CTFS plots

Chris Mullins, Robert Stallard, Carlos Sanchez, Nancy Hoalst-Pullen, Jim Dalling, Kyle Harms, and Bettina Engelbrecht

Recent work has demonstrated that the distribution of trees on BCI and Lambir can be associated with habitats defined by topographic parameters and that the dynamics of seedlings and trees may be sensitive to fluctuations in climate. Many authors have speculated that these spatial and temporal patterns in species are controlled by related patterns in soil water availability but no direct causal link has yet been established.

We are trying to model the spatial distribution of soil droughtiness by combining TOPMODEL, a spatially explicit hydrological model that calculates the contribution of overland and throughflow to the water balance for the entire landscape, and a set of measurements of the variation of soil matric potential during a single dry season at seven selected locations. Our results will show how TOPMODEL can be used as a basis for modeling soil droughtiness and hence for seeking comparisons between soil droughtiness and the distribution of species.
Forest structure and diversity of a subtropical forest plot in Fushan, Taiwan

Sheng-Hsin Su and Chang-Fu Hsieh

The first subtropical 25-ha plot was established in Fushan, northern Taiwan (24°45´40” N, 121°33´28” E). This plot is located within an old-growth montane rain forest composed of broad-leaved trees. The topographical survey, floristic inventory and enumeration of all free standing trees with >1 cm dbh were completed in September 2004.

The plot measures 500 m by 500 m. Its elevation ranges from 600 to 733 m above sea level. Annual rainfall in the Fushan area averages 4237 mm with 227 rainy days and no dry months. The annual mean temperature is 18.2 °C while the monthly averages range from 11.9 °C (January) to 24.1 °C (July). All the climatic conditions represent an extremely wet montane climate characterized by dense understory, lush ferns, abundant orchids and epiphytes.

Within the plot, we found 328 species of vascular plants (207 genera and 92 families), consisting of 87 species of trees, 50 of shrubs, 35 vines, 66 herbs, 87 ferns and 3 tree ferns. Of these species, 110 (39 families, 68 genera) were enumerated in the tree census, comprising 86 trees, 21 shrubs and 3 tree ferns. The most species-rich families were Lauraceae (12 species), Aquifoliaceae (9), Myrsinaceae (8), Rubiaceae (8), and Fagaceae (7); while the most species-rich genera were Ilex (Aquifoliaceae) (9 species), Symplocos (Symplocaceae) (7), Ardisia (Myrsinaceae) (5), and Lasianthus (Rubiaceae) (5).

In the tree census, 111,852 trees and 2,656 tree ferns were measured, identified and mapped within the 25-ha plot. Shannon’s index of diversity was 3.251 with an evenness index of 0.692. Over 50% of the abundance was concentrated in the leading 5 species. Meanwhile, 33 species had no more than 25 individuals (less than 1 individual per hectare), and 8 species were represented by a single individual. The dominant trees in the plot were Limlia uraiana (Fagaceae), Helicia formosana, Blastu. cochinchinensis, Castanopsis carlesii (Fagaceae), and Engelhardtia roxburghiana (Juglandaceae), representing 46.51% of the total importance value (IV). Among them, B. cochinchinensis stood out because of its great abundance.
Population and individual-level responses to hurricane disturbance: multiple mechanisms for successional diversity

Maria Uriarte, Jess K. Zimmerman, Charles D. Canham, and Jill Thompson

Research on the effects of disturbance as an agent of natural selection in the evolution of tree life history has focused on tradeoffs in traits that affect the ability of a tree species to colonize a site after disturbance and to retain this competitive lead as the community recovers. These tradeoffs involve mechanisms at the population and individual tree level. The latter are particularly difficult to quantify in natural tree communities since they necessitate the measurement of species-specific variation in fecundity schedules as the community recovers from disturbance. We used 11 years of seed counts and parent tree data from three consecutive 5-year censuses to parameterize spatially-explicit seed dispersal functions for 14 woody species in the Luquillo Forest Plot, Puerto Rico. Our approach allowed us to (1) obtain standardized estimates of annual fecundity in the wake of two hurricanes, Hugo in 1989 and Georges in 1998, and (2) disentangle population level response driven by recruitment of new adults from that of disturbance-driven shifts in the fecundity of surviving adults. Our results showed striking variation in annual seed production between species after the two hurricanes. We hypothesize that several species-specific factors contribute to this observed variation: (1) physical damage and regrowth of canopy, (2) changes in fecundity in response to increased light availability in the understory, and (3) changes in flower production in response to a severe drought in 1993-1994. These results illustrate the potential complexity of species variation in life-history traits that may contribute to successional diversity in tropical forests.
Forest dynamics in a large plot of Yasuni National Park, Amazonian Ecuador

Renato Valencia, Richard Condit, Consuelo Hernández, Gorky Villa, Robin Foster, and Hugo Navarrete

The Yasuni 25-ha plot was established in 1997 in evergreen, aseasonal, old-growth forest in the lowlands of eastern Ecuador, following standard CTFS methodology. A recensus was completed in 2004. In the present study, we examine the stability of this species-rich Amazonian forest in terms of species composition and stand structure. The plot included 1,104 species and 153,514 stems of juvenile and adult trees (dbh ≥ 1 cm). Tree mortality was 2% yr\(^{-1}\), and mean growth rate of all stems was 0.87 mm yr\(^{-1}\) (the maximum growth was 39.4 mm yr\(^{-1}\)). There were fewer recruits than trees lost (22,217 vs. 27,454), so on average the forest lost 34.8 stems ha\(^{-1}\) yr\(^{-1}\), which is 0.6% of the initial density. Likewise, forest basal area declined by 0.01 m\(^2\) ha\(^{-1}\) yr\(^{-1}\), or just 0.03% each year. In contrast, biomass increased by 0.53 tons ha\(^{-1}\) yr\(^{-1}\), or 0.2% of the standing stock. Small changes in overall structure, however, masked striking changes in the abundance of some species. For example, \textit{Cecropia ficifolia} more than doubled in abundance in 6 years, and \textit{Alchornea triplinervia} declined in abundance by 33% in the same period. In contrast, many species had only slight changes, exemplified by \textit{Guarea fistulosa}, whose population remained at 1,215 individuals, with 111 recruits exactly matched by 111 losses. We demonstrate that these abundance changes are greater than those predicted by a simple neutral model, demonstrating that biological forces must underlie some of them.
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