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**International Institute
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ANNUAL LETTER
1999-2000

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Dear Colleague:

With this Annual Letter we symbolically close our reporting activities for the millennium and poise ourselves for the 21st century. Notably, this Annual Letter is the first one not to be printed. Instead, it will be posted on our WEB page. We hope that by using the Internet we will be able to deliver our products more quickly and effectively. We will do our best to reach those colleagues without access to the Internet and ask that you help us as well by letting others know of this experiment, which we hope to monitor carefully. As usual, I ask that you exchange your reprints and research findings. We value these exchanges and share the information with as many people and institutions as we can.

Sincerely,

ARIEL E. LUGO
Director

ANNUAL LETTER

1999–2000

INTERNATIONAL INSTITUTE OF TROPICAL FORESTRY
RÍO PIEDRAS, PUERTO RICO

U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE

INTERNATIONAL INSTITUTE OF TROPICAL FORESTRY ANNUAL LETTER 1999–2000

Contents

LONG-TERM AVIAN RESEARCH

Wayne J. Arendt
Research Wildlife Biologist

PUERTO RICAN PARROT RESTORATION AND RELATED RESEARCH

With the publication of a parrot conservation and management article (Arendt 2000), there arose a renewed interest in developing a safe method for controlling levels of ectoparasitic botflies (*Philornis* sp.) in birds' nests. Various avenues of cooperative research are currently being explored involving entomologists and wildlife researchers at two stateside universities. In lieu of traditional pesticides with their many well known disadvantages, researchers are working fervently to develop all-organic biocides, namely volatile plant secondary compounds, which they hope eventually can be safely introduced into nests of the critically endangered Puerto Rican Parrot and other forest cavity-nesting birds to deter botfly ectoparasitism. Also, as a result of more than 20 years of research into the reproductive ecology of the Pearly-eyed Thrasher, the parrot's prime nest predator, related cooperative research has begun with Drs. Steven Beissinger and Mark Cook, professor and postdoctoral candidate, respectively, of the University of California at Berkeley. The cooperative research involves a series of egg experiments to determine the onset of incubation in the Pearly-eyed Thrasher as well as various ancillary parameters. Following are some brief excerpts summarizing our preliminary findings and presented by the UC-B cooperators:

Egg Hatching Summary

In total, 260 eggs were laid during the 2000 breeding season in 43 nest boxes, and 114 (43.8 percent) hatched. Of these 260 eggs, 41 failed to hatch due to factors unrelated to experimental treatment and were excluded from analyses. The remaining 219 eggs comprised 16 controls, 37 unmanipulated and 166 treatment eggs.

Hatching Success

Hatching success of control eggs (14 of 16 hatched or 87.5 percent) and unmanipulated eggs (32 of 37 eggs or 86.4 percent) was similar suggesting that moving eggs between sites had little affect on hatchability (G-test of independence with Yates's correction: G=0.66, df=1, P>0.50). Although the transportation period was longer on average for treatment eggs (151.9 ±113.5 *sd*) than for control eggs (101.38 ±64.4 *sd*), the difference was not significant (Mann-Whitney test, $U_{16,153}$=952, P=0.14). Thus, potential effects on hatchability of the amount of time an egg was transported were unlikely to confound comparisons between control and treatment groups in this study.

Hatching success (40.9 percent, n=166 treatment eggs) markedly declined with increasing exposure period but differed little among holding box sites. Hatchability of experimental eggs after 1 day of exposure (83.3 percent hatched) was not significantly lower than control eggs (G-test of independence: G=0.21, n=101, df=1, P>0.50), but was significantly reduced after exposure of 3 days (47.6 percent hatched, G=80.05, n=95 df=1, P<0.001), 5 days (22 percent hatched, G=39.74, n=89 df=1, P<0.001), and 7 days (G=87.54, n=93, df=1, P<0.001). No 7-day treatments hatched.

Preincubation Development

Initiation of incubation relative to clutch completion in the thrasher is variable. Full incubation proceeds upon laying of the penultimate egg in some broods, whereas in others, full incubation starts upon clutch completion. Thus, the onset of incubation is variable with respect to all but last-laid eggs.

Mean incubation periods of all treatment eggs (14.7 days ±0.6 *sd*, n=64) were slightly, but significantly (t_{75} =2.08 P=0.041), longer than those of the pooled control/unmanipulated eggs (14.2 days ±1.1*sd*, n=13).

Therefore, contrary to prediction, experimental treatment appeared to increase embryo development time rather than decrease it. However, caution must be exercised when interpreting this result since the mean difference between the two groups (0.5 days) was less than the sampling period unit (1 day).

Timing of Embryo Mortality

Of the pooled set of 53 control and unmanipulated eggs, only 7 eggs failed to hatch. Each one was assessed for stage of embryo mortality. Control-egg embryos mostly died after no development (57 percent; embryo age 0 to 1d) or little development (43 percent; embryo age 2 to 4d), and none reached an advanced level of development (embryo age 9 to 13d). Stage of embryo mortality was also recorded for each of the 98 treatment eggs that failed to hatch. The pattern of embryo mortality in treatment eggs was similar to that of control eggs. The majority of eggs showed no (63 percent) or little development (16 percent), with only 14 percent and 4 percent reaching moderate (embryo age 5 to 8d) and advanced levels of development, respectively.

LONG-TERM STUDIES IN THE GUANICA DRY FOREST

The annual mist netting and banding of Guánica's forest birds took place in January 2000, marking the 28th year of this long-term study of forest-bird populations. We continue to investigate the various environmental effects on population dynamics of resident and migratory birds (Dugger and others, in press) in an effort to develop appropriate management and conservation strategies to ensure sustainable avian populations for future generations (Faaborg and others, in press). By continuing our long-term research in Guánica, we have been able to substantiate an earlier preliminary finding; i.e., that populations of Nearctic-neotropical migrants that winter in the forest, although fluctuating widely over the years, have declined slowly but steadily since the mid-1970's. It is encouraging, however, that the dominant wintering migrants (black-and-white warbler *Mniotilta varia*, American redstart *Setophaga ruticilla*, and ovenbird *Seiurus aurocapillus*, show stable or only slightly declining populations.

Modeling Avian Survival Constrained by Rainfall

Most recently, we have been modeling the survival of Guánica's forest birds by factoring in the constraints of rainfall. As found previously when we correlated avian population fluctuations with total and first 6-month precipitation levels after 9 and then 15 yr (Faaborg 1982, Faaborg and Arendt 1992, Faaborg and others 1984), over a 26-yr period, annual survival of individuals within and among all foraging guilds, but especially frugivores, was greatly constrained by total levels of precipitation, and mainly during the first 6 months of the year (Dugger and others, in press).

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BIG-LEAF MAHOGANY GROWTH STUDY: YEAR 2 PROGRESS REPORT

October 1, 1999 to September 30, 2000

Julio C. Figueroa Colon
Ecologist

Summary

The original objectives of this study remain: (1) to establish a rangewide network of permanent study plots, which will allow for the description, comparison, and monitoring of natural big-leaf mahogany populations across the entire environmental gradients of climate and soils in which it occurs; and, (2) to produce much needed growth data from a variety of sites, which can be used by conservationists and managers alike. Accomplishments for this past year and findings to date are summarized in this report along with a proposed work schedule for the coming year.

Protocols

Three different sites, each with varied climatic, topographical, and logistical characteristics, have been completed, and the study protocols designed for this study have proved both proficient in the quality of data collected, as well as efficient in the time and ease of implementation. Proficiency in the methodology now allows us, a team of 2 (with 2 to 3 field hands) to locate, grid, and GPS a 25-ha study block into 25 individual 1-ha plots; locate and GPS an additional 25 individual 0.04-ha subplots; and then measure and GPS all tallied trees, all in 3 to 4 weeks.

Study Sites

Two new sites were selected, established, and measured during this past year: Quiringuicharo-Chiapas-Mexico and Capixaba-Acre-Brazil.

Quiringuicharo—This study site was located in natural wet tropical forests in the municipality of Benemerito de Las Americas in southeastern Chiapas, Mexico. In summary, a total of 37 mahoganies, d.b.h.>= 10 cm, were encountered and tallied within the 25-ha study block, for an average of 1.4 trees per ha. Mean d.b.h. was 63.5 cm, and 54 percent of the stems tallied were over 60 cm in d.b.h. A total of 14 mahogany individuals, d.b.h.< 10 cm, were tallied in the regeneration plots (1 sapling and 13 seedlings), for an average of 13.2 per ha.

Capixaba—This study site was located in natural tropical moist lowland forests in the municipality of Capixaba in southeastern Acre, Brazil. In summary, a total of 8 mahoganies, d.b.h.>= 10.0 cm, were encountered and tallied within the 25-ha study block for an average of 0.3 trees per ha. Mean d.b.h. was 86.4 cm, and 63 percent of the stems tallied were over 60 cm in d.b.h. No mahoganies were encountered in the regeneration sampling, neither saplings nor seedlings.

Workplan for Year 3

The main objectives must continue to be the establishment and measurement of additional study sites. After three completed study sites, several combinations within the environmental gradient matrix of the species' distribution have been covered (table 1). Also, results to date suggest that big-leaf mahogany population structure appears to be sensitive to disturbance patterns. Figure 1 shows percentages of total mahogany individuals by diameter-size class within 25-ha blocks. The one site with a periodic disturbance regime (Bacalar) shows a distinct preponderance of smaller size classes and few large individuals when compared to the other two more environmentally stable sites. The objective for this coming year is to select three additional differing sites that will complement those already completed. Particular emphasis is being put into identifying sites on volcanic substrates and montane habitats.

Table 1—Environmental gradient matrix for big-leaf mahogany study sites

	Climate		
Soils	Dry (<1500)	Moist (1500–2500)	Wet (>2500)
Limestone	Bacalara[a] Belize	Belize[b]	Belize[b]
Alluvial	—	Capixaba[a] Peru	Quiringuicharo[a] Feijo, Brazil[c] Para, Brazil[c]
Volcanic	Oaxaca, Mexico[b]	Oaxaca, Mexico[b]	—
Montana	—	Oaxaca, Mexico[b]	Peru[b]

[a] Completed sites.

[b] Potential unconfirmed sites.

[c] Potential confirmed sites.

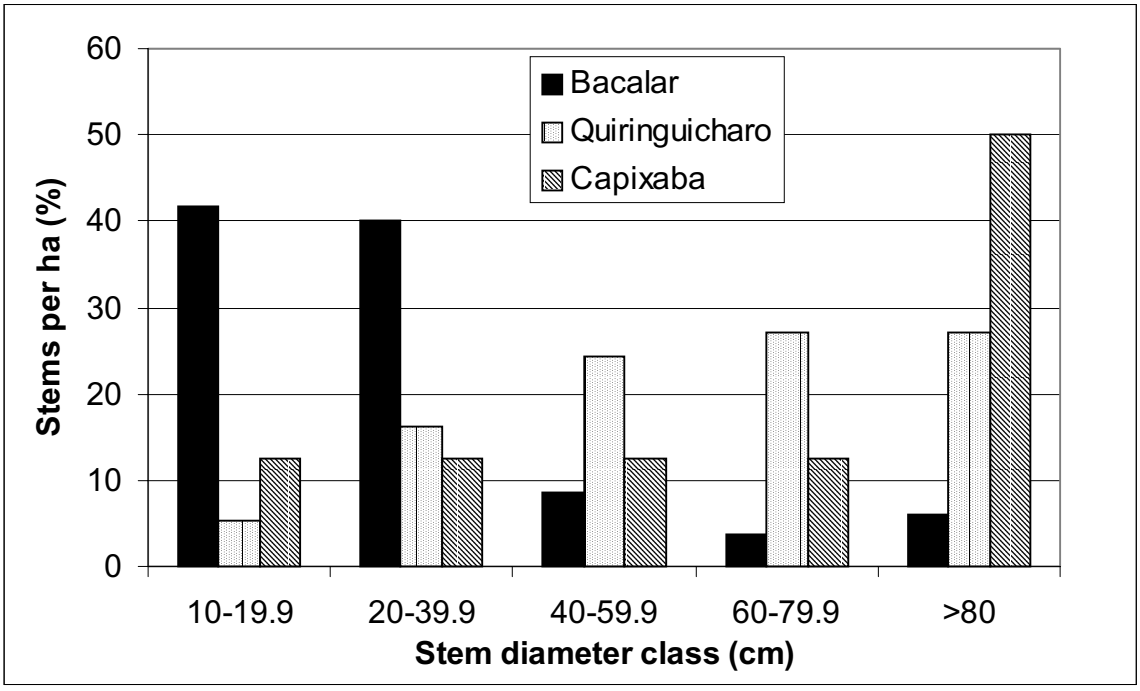

Figure 1—Comparative summary of diameter-size class distributions for big-leaf mahogany individuals tallied in study sites in Mexico (Bacalar, Quiringuicharo) and Brazil (Capixaba). Some environmental characteristics of the study sites may be gleaned from table 1.

I STILL LOVE THE TREES, BUT . . .

John K. Francis
Research Forester

It is almost the end of an era. Seventeen years ago scientists of the International Institute of Tropical Forestry (IITF) and other local institutions began a silvics manual of tropical trees in Puerto Rico. One hundred and two species of trees significant to the Caribbean were described in detail. The English version, printed as separate short monographs in 3-hole format, has been available for some time. A Spanish translation has been completed, editing and formatting have been preformed, and it is being printed as a bound volume (Francis and Lowe 1999). Copies should be available at the IITF library during the first part of January 2001. It may be viewed on the IITF website (http://www.fs.fed.us/global/iitf/research/research.html) under "Article: Silvics of Native and Exotic Trees." A compendium of information drawn from the silvics manual and other planting research preformed over the years in Puerto Rico is also available in English and Spanish (Francis 1998, 1999). Another publication concerned with trees' resistance to hurricanes in Puerto Rico should also be noted. Percent defoliation, crown loss, and snap plus throw were estimated for a large number of individual trees of 24 species in the UPR Botanic Garden area, and comparisons were made of the relative resistance of these species. Small leaf mahogany (*Swietenia mahagoni*) proved to be the most resistant overall and African tulip tree (*Spathodea campanulata*), the least resistant (table 1). Statistical comparisons and models are presented in the publication (Francis 2000).

Table 1—Species and means of trees sampled and the percent defoliation, percent crown loss, and percent snap plus throw

Species	D.B.H.	Ht	%Def.	%Cl	%S-T	No.
Swietenia mahagoni	28.5	10.7	70.7	22.7	0	50
Hymenaea courbaril	38.0	17.3	89.6	40.6	2	50
Calophyllum calaba	34.8	15.2	77.3	41.0	6	50
Pinus caribaea	37.2	17.7	51.8	41.8	6	50
Melaleuca quinquinervia	26.6	8.8	52.4	43.2	10	39
Dalonix regia	36.3	10.9	70.2	43.8	2	49
Lagerstromia speciosa	48.5	11.5	77.0	44.0	2	50
Terminalia catappa	46.6	14.9	86.6	46.5	2	41
Tabebuia heterophylla	23.7	10.3	73.2	47.4	4	50
Cassia javonica	43.9	10.5	87.7	47.4	10	31
Casuarina equisetifolia	54.0	20.6	62.0	49.8	4	50
Pterocarpus macrocarpus	76.4	20.7	94.5	50.7	6	50
Bucida buceras	33.6	13.4	80.7	50.7	2	50
Enterolobium cyclocarpum	113.6	17.5	87.6	50.8	9	33
Mangifera indica	64.5	12.6	66.8	51.7	2	50
Clitoria fairchieldiana	26.0	4.7	62.0	51.9	38	32
Ficus benjamina	68.6	9.1	56.5	52.5	30	50
Schefflera morototoni	16.4	10.1	91.3	56.4	30	50
Albizia procera	34.2	18.8	97.3	59.7	22	50
Cecropia sherbertiana	24.5	12.7	94.5	60.6	24	34
Sterculia apetala	33.1	12.9	94.9	63.7	21	34
Peltophorum pterocarpum	38.6	15.4	89.5	65.6	12	33
Senna siamea	30.3	16.2	94.9	66.5	10	50
Spathodea campanulata	41.6	16.9	98.1	81.1	34	50

I still love trees, but we woodsmen always have another ridge to cross and another horizon to view. There are shrubs growing on the other side of that mountain—thousands of them and each practically unknown. A survey of the literature reveals that there are over 500 species of shrubs in Puerto Rico and approximately 2,500 species in the United States and its territories. It is impossible to fix an exact number of shrub species for a region because the definition of just what a shrub is (what characterizes a shrub) cannot be very precise. I personally believe that as long as a plant is not clearly a tree or an herb, and as long as we recognize the ambiguity of its form, it is of no consequence to describe and understand it.

In cooperation with the Shrub Sciences Laboratory in Provo, Utah, I have begun a national wildland shrubs handbook. It is being produced along the lines of the U.S. Silvics Manual. Each species' monograph is limited to two printed pages because of the large number of species to be treated and the paucity of information available for most of them. I intend for the manual to be useful and as easy to read as possible. An introduction, format for submissions, and eight monographs are complete. The volume to date and each new monograph will be posted on the IITF website (early 2001) and eventually published as a book. Persons interested in submitting a monograph should view the web page (as soon as it is available) or contact the coordinator, John K. Francis, at IITF.

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LANDSCAPE ECOLOGY AND REMOTE SENSING PROGRAM

Eileen Helmer
Ecologist

During 1999-2000, the Landscape Ecology and Remote Sensing Program at the IITF used Landsat TM satellite imagery to map land use and natural vegetation for the entire island of Puerto Rico. The map contains 17 types of woody vegetation, including 5 successional forest formations. This is the first such map done for the island and the first map of land cover completed since 1978. The IITF has also begun a Caribbean-wide mapping effort, the Caribbean Mapping Initiative, in partnership with the U.S. Geological Survey EROS Data Center, The Nature Conservancy's International Headquarters, and the U.S. National Aeronautics and Space Administration (NASA). Through the Global Observation of Forest Cover program, NASA has awarded funds for the purchase and preprocessing of Landsat 7 satellite imagery for all of the Caribbean islands and portions of the Guyana Shield. This mapping effort will be the first of its kind for the Caribbean region and will provide baseline data for ecosystem management analyses related to biodiversity conservation, forest carbon, and hazard mitigation.

ECOLOGICAL RESEARCH

Ariel E. Lugo
Ecologist

This year my publications with various collaborators focused on seven topics. The topics were: (1) ecosystem management (Lugo 1999d, Lugo and others 1999a, Lugo and Brown 1997); (2) roads (Lugo and Gucinski 2000); (3) mangroves (Lugo 1999a, 1999b, 1999c; Lugo and others 1999c); (4) hurricane disturbances (Lugo and others 2000b); (5) biodiversity (Ewel and others 1999, Lugo and Brown 2000); (6) mapping of life zones (Lugo and others 1999b); and (7) the vegetation of the Caribbean (Lugo and others 2000a). In addition, I edited a proceedings volume with Carleen Yocum (Yocum and Lugo 2000) and reviewed a book on climate change (Lugo 2000). The findings of some of these publications are highlighted below.

ECOSYSTEM MANAGEMENT

I analyzed arguments against active tropical forest management in light of available data and new research that show tropical forests to be more resilient after disturbances than previously thought. Tropical forest management involves a diverse array of human activity embedded in a complex social and natural environment. Within this milieu, forest structure and composition adjust to change and reflect the human and natural economy of regions. Critics of active forest management overestimate problems and underestimate the human capacity to solve them. They isolate parts of a complex issue, i.e., the biodiversity component of tropical forest management, to generalize about the negatives of logging. This view of the Tropics is consistent with past treatment of tropical issues by those that evaluate the situation from a nontropical perspective. The literature reveals that conservation of biodiversity can be compatible with measured use of tropical forests. However, the conservation of biodiversity could be hurt should society not approach the tropical forestry issue holistically and act on misinformation. Action forest management is the means toward the goal of conservation and the best available way to simultaneously address human needs and conservation of biodiversity. However, active forest management requires the application of emerging paradigms of ecosystem management (Boxes 1 and 2).

FOREST ROADS AS ECOSYSTEMS

Gucinski and I proposed a unified approach to the management and analysis of the function and effects of roads on forested rural landscapes. The approach is based on considering roads as ecosystems (techno-ecosystems; fig.1) and conducting analyses of road ecology prior to making policy or management decisions. An ecosystem approach to road issues has four advantages: (1) allows for the analysis of all types of roads irrespective of geographic location; (2) provides a holistic framework for analyzing all aspects of roads from their alignment to their operation and decommissioning as well as all road functions regardless of value judgment; (3) provides a holistic focus to their management; and (4) supplements landscape management approaches based on spatial concepts.

We present five precautions to be considered when evaluating road ecosystems: (1) identify the type of road under consideration; (2) differentiate the effects and conditions of individual road segments from those of road networks; (3) be explicit about the phase of road development to which the argument applies because different phases of development have different effects on the landscape; (4) ascertain the age of the road and evaluate the degree of landscape adjustment to the road and vice versa; and (5) not to prejudge human-induced changes in landscapes as automatically good or bad for the ecology or economy of a region. This ecosystem focus and guiding principles are applied to several issues that road policy and management activities must address.

Box 1

Paradigms of Ecosystem Management

Advancement in ecosystem science has led to new paradigms in resource management. These are listed below with the resource management paradigms they replace.

- A non-steady-state concept of the ecosystem (as opposed to a focus on climax or balance ecosystems).
- Managing from the perspective of resilience (as opposed to stability).
- Considering disturbance an integral part of ecosystems, required to maintain them (as opposed to suppressing or ignoring catastrophic factors).
- Considering past land use legacies, all species, and the dead mass (necromass) of ecosystems, (as opposed to focusing only on the present state of the site and the live component of a few species and populations).
- Focusing greater attention on the connections within and between ecosystems, particularly the interface of land, water, and atmosphere (as opposed to focusing only on the site under management).
- Considering all time and spatial scales (as opposed to focusing only on short-term and small geographic scales).
- Maintaining a global and long-term perspective even when managing at small scales (as opposed to a short-term, local perspective).
- Restoring whole ecosystems (as opposed to only rehabilitating land and water productivity).

MANGROVES

Mangroves are the subject of a struggle between those who want to maximize economic benefit through intensive uses of the system (sometimes at the cost of eliminating the biota in favor of urban or other developments) and those who advocate complete preservation of the ecosystem even at the exclusion of people. As tropical countries continue to develop economically, their governments must balance the various uses of mangroves and other coastal areas to assure sustainability of development. However, this will not be possible without a constant flux of scientific information on these ecosystems. Scientists must provide accurate information upon which resource managers and policy makers can base their decisions.

Box 2

Some Principles of Ecosystem Management

- Follow nature's lead. Mimic natural disturbance patterns and recovery trends in your area.
- Think big. Manage for landscape diversity as well as within-stand or patch diversity, and maintain the largest possible contiguous patches of ecosystems of concern.
- Don't throw out any of the pieces. Maintain a diverse mix of genes, species, biological communities, and regional ecosystems.
- Side with the underdogs. Set priorities in favor of the species, communities, or processes that are threatened or otherwise warrant special attention.
- Try a different tool. Diversify management approaches and reduce the emphasis on complete conversion of ecosystems.
- Keep your options open. Use existing infrastructure of resources wherever possible.
- No ecosystem should be an island. Minimize fragmentation of continuous ecosystems by exploiting areas near existing clearings and by nibbling away at the edge instead of creating a new hole.
- Encourage free travel. Create a web of connected habitats. Leave broad travel connectors for plants and animals, especially along streams and ridge tops.
- Leave biological legacies. Select what to leave behind as carefully as what to take out; specifically, leave standing live and dead trees and fallen trees in managing forests.
- Leave it as nature would. Leave a mixture of tree sizes and species on the site. Restore naturally diverse forests after harvest.
- Be an information hound. Use the latest studies and state-of-the-art technologies to design, monitor, and evaluate new approaches.
- Be a critical thinker. Use only the scientific findings that make sense for your region and social setting.
- Monitor, monitor, monitor. Monitoring is the only sure way to tell if you are really conserving biological diversity.

Mangrove forests are tough ecosystems to invade because few species can tolerate the hydrological and edaphic conditions that prevail in mangrove habitats. The small pantropical mangrove species pool is also the basis for asserting that mangrove forests are easy to rehabilitate, at least in terms of tree species composition. The following questions are useful as a guide for evaluating the invasion of plant species into mangrove habitats: (1) Is the invading species a halophyte? (2) What conditions of the environment are the invading species occupying, and how long will those conditions last? (3) What is the geographic location of the invasion, does it penetrate the forest, or is it only at the edge? (4) Is the invasion a short-term response to changes in microsite conditions? (5) Is the invasion the result of a long-term shift in the mangrove habitat?

It appears that the use of models for planning research is a valuable tool for programs involving one or many researchers attempting to understand the regional relationships among ecosystem types. A preliminary model of a mangrove forest in south Florida has yielded the following information that was not apparent from examination of data prior to the present study:

1. Mangrove forests appear to reach a steady state with respect to their biomass in phase with the frequency of tropical hurricanes in regions where they occur.

2. The storage of organic detritus in the forest and its export to the bays are a function of tidal amplitude, but tides do not seem to affect gross photosynthetic rates as much as they affect detritus accumulation versus export.

3. Gross photosynthesis appears to be sensitive to terrestrial input of nutrients, and the development of mangrove biomass is dependent on the quantity of nutrients and the efficiency of nutrient uptake.

4. Mangrove zonation and vigor may thus be a function of nutrient availability rather than solely salinity as previously thought.

5. During succession, mangroves exert significant control over the amount of nutrients in adjacent waters, but, if terrestrial runoff is reduced, they do not have the capacity to maintain themselves at the same level of production. This is due to loss of nutrients in detritus export to the bays and suggests that there must be selective pressure for mechanisms of recycling within the mangrove forest.

HURRICANES, CORAL REEFS, AND RAINFORESTS

The coexistence of hurricanes, coral reefs, and rainforests in the Caribbean demonstrates that highly structured ecosystems with great diversity can flourish in spite of recurring exposure to intense destructive energy (tables 1, 2). Coral reefs develop in response to wave energy and resist hurricanes largely by virtue of their structural strength. Limited fetch also protects some reefs from fully developed hurricane waves. Whereas storms may produce dramatic local reef damage, they appear to have little impact on the ability of coral reefs to provide food or habitat for fish and other animals. Rainforests experience an enormous increase in wind energy during hurricanes with dramatic structural changes in the vegetation. The resulting changes in forest microclimate are larger than those on reefs, and the loss of fruit, leaves, cover, and microclimate has a great impact on animal populations. Recovery of many aspects of rain forest structure and function is rapid though there may be long-term changes in species composition. Whereas resistance and repair have maintained reefs and rainforests in the past, human impact may threaten their ability to survive.

INTRODUCTIONS OF SPECIES

Ewel and others (1999) sought scientific consensus on the controversy of species introductions. Box 3 contains research questions that emerged from the analysis.

THE LIFE ZONES OF THE UNITED STATES

Aim—Our main goals were to develop a map of the life zones for the conterminous United States, based on the Holdridge Life Zone system, as a tool for ecosystem mapping, and to compare the map of Holdridge life zones with other global vegetation classification and mapping efforts.

Table 1—Approximate kinetic energy dissipation rates from wind and waves. For comparison, the 24-hr mean solar energy input to the rainforest or coral reef is about 185 joules $m^{-2}s^{-1}$. Explanations are reported in Lugo and others 2000b

Winds and waves	Kinetic Energy
	(*joules* $m^{-2}s^{-1}$)
Winds	
Global yearly average wind	0.014
Wind over Lake Mendota, Wisconsin, U.S.A.	0.003 – 0.015
Winter storm wind, Long Island Sound, U.S.A.	2
Winds from Hurricane Daisy	
0 to 37 km radius core	1.6
37 to 74 km radius ring	72
74 to 111 km radius ring	38
111 to 148 km radius ring	27
Area-weighted mean	47
Waves	
Yearly average waves on Grand Cayman Island Coral Reef, Caribbean Sea	20 – 25
Zones of maximum wave energy form trade winds, Bikini Atoll Reef, Pacific Ocean	200 – 300
Waves on exposed rocky coast, Northeast Pacific	3,000
Maximum waves from Hurricane Allen on Jamaican coral reefs	550,000 –750,000

Location—The area of interest is the 48 contiguous States of the United States.

Methods—We wrote a PERL program for determining life zones from climatic data and linked it to the image processing workbench (IPW). The inputs were annual precipitation (Pann), biotemperature (T_{bio}), sea-level biotemperature (T_0bio), and the frost line. The spatial resolution chosen for this study (2.5 arc-minute for classification, 4-km for mapping) was driving by the availability of current state-of-the art, accurate, and reliable precipitation data. We used the Precipitation-elevation Regressions on Independent Slopes Model, or PRISM, output for the contiguous United States download from the Internet. The accepted standard data for air temperature surfaces were obtained from the Vegetation/Ecosystem Modeling and Analysis Project (VEMAP). This data set, along with station data obtained from the National Climatic Data Center for the U.S., was used to develop all temperature surfaces at the same resolution as the Pann.

Results—The U.S. contains 38 life zones (34 percent of the word's life zones and 85 percent of the temperate zones) including 1 boreal, 12 cool temperate, 20 warm temperate, 4 subtropical, and 1 tropical. Seventy-four percent of the U.S. falls in the 'basal belt', 18 percent is montane, 8 percent is subalpine, 1 percent is alpine, and <0.1 percent is nival. The U.S. ranges from superarid to superhumid, and the humid province is the largest (45 percent of the U.S.). The most extensive life zone is the warm temperate moist forest, which covers 23 percent of the country. We compared the Holdridge life zone map with output from the BIOME model,

Table 2—Some similarities and contrasts between coral reefs and rainforests

Similarities	
Canal needs	Rain forest
High diversity of reef and rainforest types	Fast development of photosynthetic tissue
Large number of species	High respiration
Complex food webs	Resistance and resilience strategy for storms
High species dominance	Life history traits of dominant species reflect responses to disturbances
Day/night shifts in activity	Asexual reproduction of corals and resprouting of trees after storms
High photosynthesis	Delayed mortality after storm damage
Contrasts	
Coral reefs	Rainforest
Topography is mostly biogenic	Topography is tectonic
Carbonate substrate does not provide nutrients	Soil provides most of the nutrients
Low biomass of organisms	High biomass of organisms
Plants inconspicuous	Plants conspicuous
Animals easily visible	Animals less visible
Algae controlled by herbivores	Producers not controlled by herbivores
High degree of symbiosis	Moderate degree of symbiosis
Low coral species turnover at 0.1-ha level	High tree species turnover at 0.2-ha level
30 animal phyla represented	15 animal phyla represented
Alien species not important	Alien species are a concern
Disease conspicuous	Disease not conspicuous
Larvae are pelagic, dispersed by currents	Animals disperse seeds
Larvae disperse thousands of km	Seeds disperse hundreds of km
Water, nutrients, larvae and fish transported by currents	Water, gases, and some nutrients transported by wind
Close physical proximity between photosynthesis and respiration	Photosynthesis and respiration physically distanced
Low nutrient accumulation on sediments	High nutrient accumulation belowground
Slow turnover variables[a] are wave regime and calcium carbonate structure	Slow turnover variables are topography and soil
Intermediate turnover variables include large fish and organic sediments	Intermediate turnover variables are large trees
Fast turnover variables include water, plankton, algae, and microbes	Past turnover variables include leaves, animals, and microbes

[a] The rate of turnover is classified relative to other rates within each system. There are also potentially interesting and important comparisons of rates between systems.

Box 3

Research Questions About Introductions

Several research questions need to be answered to help ensure that proposed introductions are done wisely and safely.

Guarding against risks without sacrificing benefits:5

- How can the potential benefits and costs of introductions best be evaluated in economic, environmental, and social terms?
- Should all introductions be regulated?
- How different must organisms or recipient ecosystems be from those assessed previously to warrant independent assessment?
- When is it appropriate to assess and regulate taxa other than species?
- What are appropriate ecological and political boundaries for regulation?

Alternative to introductions:

- How and when can indigenous organisms be domesticated so that they can substitute for proposed uses of nonindigenous organisms?
- How can the retention of indigenous species and natural food webs be integrated into agroecosystems so that the risk of pest problems is minimized?

Purposeful introductions:

- What common guidelines can be developed for deliberate introductions of all kinds of organisms?
- Have screening procedures differed for introductions that proved successful or harmful?
- How can the potential for nonindigenous organisms to disrupt ecosystem processes be assessed and reduced?
- Can the demand for introductions be reduced by improving the effectiveness of introductions that are attempted?

Reducing negative impacts:

- When can reduction of human-caused disturbance within natural areas be used to control nonindigenous species impacts?
- Can subtle, indirect effects of potential introductions be predicted?
- Can enough be learned from the population growth lags, booms, and crashes of previously introduced organisms to make useful generalizations?
- Should special guidelines accompany release of sterile forms, which may pose less risk than fertile organisms?
- Can protocols be developed to predict when an introduced species will hybridize with natives and what the ecological and economic consequences of such hybridization might be?
- Should special guidelines related to invasion and hybridization potential be added to those that already regulate release of genetically engineered organisms?

Bailey's ecoregions, Küchler potential vegetation, and land cover—all aggregated to four cover classes. Despite differences in the goals and methods for all these classification systems, there was a very good to excellent agreement among them for forests but poor for grasslands, shrublands, and nonvegetated lands.

Main conclusions—We consider the life zone approach to have many strengths for ecosystem mapping because it is based on climatic driving factors of ecosystem processes and recognizes ecophysiological responses of plants. It is hierarchical and allows for the use of other mapping criteria at the association and successional levels of analysis. It can be expanded or contracted without losing functional continuity among levels of ecological complexity. It is a relatively simple system based on sparse empirical data. It uses objective mapping criteria.

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FOREST MANAGEMENT AND REHABILITATION RESEARCH

Healing Plants of Peninsular India

John A. Parrotta
Reseach Forester

During FY2000, work was completed on a project initiated in 1994 to describe and document the traditional medicinal uses of forest plants in peninsular India. The primary purpose of this project has been to synthesize existing knowledge on the botany, ecology, and traditional uses of Indian medicinal plants in a form that is accessible to a broad spectrum of potential users and the general public. This resulting book, to be published by CAB International in early 2001, focuses on the flora characteristic of the deciduous forest zone that includes nearly all of central India south of the Indo-Gangetic Plain and interior regions of Southern India. It includes detailed information on the botany, geographical ranges, habitat preferences, and traditional medicinal uses (in Ayurveda, Unani, Siddha, folk, and tribal medicine) of 545 plant species, each illustrated with color photographs taken during field excursions in several Indian States in 1994 and 1997. The book's introduction examines the cultural and historical development of traditional Indian medicine and research on plant drugs in an international context, as well as the current distribution and status of India's forests and medicinal plant resources. Species descriptions include their common names in the 14 major languages of the sub-Himalayan region (including English and Sanskrit). Specialized glossaries and indices of medicinal uses as well as common names in English, Sanskrit, and regional Indian languages are also provided.

AN EVALUATION OF DIRECT SEEDING FOR REFORESTATION OF DEGRADED LANDS IN CENTRAL SÃO PAULO STATE, BRAZIL

Vera Lex Engel[1] and John A. Parrotta

As part of a larger study evaluating several silvicultural techniques for restoring tropical moist forests on abandoned agricultural lands in southeastern Brazil, direct seeding with five early successional Atlantic forest species was tested at three degraded sites, characterized by different soil types and land use histories, within the Environmental Protection Area at Botucatu, SP. The species used in this study were *Chorisia speciosa, Croton floribundus*, *Enterolobium contorstisiliquum, Mimosa scabrella* and *Schizolobium parahyba*. Scarified seeds of each of these species were sown in prepared seed spots in replicated, 0.25-ha mixed-species plots at an initial spacing of 1 by 1 m at each site. Of the five species planted, only two, *Enterolobium* and *Schizolobium*, showed good seed germination, seedling survival, and early growth rates, averaging 4.1 to 4.6 cm stem diameter and 0.8 to 0.9 m height growth during the first 2 years after sowing. These two species constituted 88 to 100 percent of the total stand density, which ranged from 1050 to 1790 stems ha^{-1} at 2 years. Despite the poor performance of the other species tested, we observed that the natural regeneration of native forest species originating from remnant forests in the general vicinity of our study sites was significantly greater within the direct-seeded plots than in unplanted control plots that were protected from fire and other disturbances.

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Native tropical forest rehabilitation: a case study from Brazil. Invited paper presented at XXI IUFRO World Congress, Kuala Lumpur, Malaysia; 2000 August 7–12.

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ECOSYSTEM RESEARCH

F.N. Scatena
Hydrologist

The past year was as busy as ever but will probably be remembered for four important events:

- No hurricanes passed the island, and we had only one hurricane warning. After several years of hurricane worries, this was a great relief for all at IITF.

- Dozens of healthy tabonuco (*Dacryodes excelsa* Vahl.) seedlings were found in and around the Sabana field station. During the past year seed, rain, and regeneration of this species have been abundant within the forest. However, this is the first time we have seen this important species regenerating under advanced secondary vegetation so far away from closed tabonuco-type forest. We are keeping a close watch on these true pioneers.

- Massive upstream migrations of fish and snails were observed in the rivers of the Luquillo Experimental Forest. In June and July, we saw several large schools of the mountain mullet (*Agonostomus monticola*) "jumping like salmon" as they migrated upstream. Large schools were seen in the Mameyes at Puente Roto in mid-June and in the Espirtu Santo River near the Girl Scout camp in mid-July. When questioned, several long-term residents of the area who are also avid fisherman said they have never seen anything like this before. Starting in September and continuing until December 2000, we also witnessed 5 massive upstream migrations of the freshwater snail *Neritina* in the Río Mameyes near Route 3. Although these migrations have been described before, this is the first time we have been able to follow them and carefully document the migrations. Based on our initial information of their rate of migration, we estimate it may take more than 5 years for these snails to make it all the way to Puente Roto.

- The construction of the new IITF laboratory and sample storage facilities in Río Piedras began. This has been in the planning for several years and will greatly improve our ability to conduct research and provide services to our collaborators.

In addition to these historic events, we continued to have an active collaborative research program. Moreover, the Sabana Field Station has been occupied throughout the year with students and collaborators from the University of New Hampshire, University of California at Berkeley, University of Puerto Rico, SUNY-Stony Brook, SUNY-Environmental Science and Forestry, and the Vrije Universiteit of Amsterdam. In addition to investigators from the United States and Puerto Rico, students and investigators from Singapore, Holland, Germany, Panama, Colombia, and Guatemala worked with us in the Luquillo Experimental Forest.

During the fiscal year, two new projects were also established. The first was under the direction of Dr. William McDowell of the University of New Hampshire. This project, which is funded by a U.S. Department of Agriculture competitive grant, is focused on understanding nitrogen dynamics in the forests of Bisley and the Río Icacos. The second large project was a year-long micrometeorological study of the Luquillo climatic gradient under the direction of Prof. Hans Vugts and students from the Vrije Universiteit of Amsterdam.

In our continuing effort to promote the transfer of scientific knowledge for the management of aquatic resources, we co-sponsored a meeting on the management of Puerto Rican streams at the Society of Puerto Rican Engineers. The meeting was organized with the U.S. Fish and Wildlife Service and the local engineering firm Gregg Morris and Associates. The meeting was attended by over 85 engineers and natural resource managers from throughout the island.

Participants from the U.S. Geological Survey, the Army Corps of Engineers, the Natural Resource and Conservation Service, the Puerto Rican Departments of Highways and Natural Resources, and environmental officers from several municipalities attended the conference.

This year also marks the first year of the Caribbean AMIGO project on Regional Hydrology. This is a multinational volunteer effort aimed at developing integrated hydrological analysis. During the year, the AMIGO web page was established (http://biblioteca.imta.mx/amigo/), and several projects on ecohydrology, extreme events, droughts, and data management were started. At an international meeting sponsored by the International Hydrological Program, the AMIGO group presented a paper that will be published shortly on natural disturbances and the hydrology of humid tropical forests.

CONTINUED STUDIES ON MAHOGANY AND LONG-TERM PLOTS AT THE LUQUILLO EXPERIMENTAL FOREST

Sheila Ward
Ecologist

The emphasis of this year's work was again on mahogany. The mahogany provenance study in Puerto Rico was planted in the 1960's at 14 sites in Puerto Rico and St. Croix, U.S.VI, from dry to wet forest sites, using 20 provenances collected from Mexico, Central America, and the Caribbean. This year, material from this study is being included in a phylogeographic analysis of population differentiation of *Swietenia macrophylla* using restriction fragment length polymorphisms in chloroplast DNA. The Institute of Terrestrial Ecology (ITE, Scotland) and CATIE (Costa Rica) are heading up this project. Puerto Rican *Cedrela odorata*, and representatives of the genus *Toona* that are in the IITF Arboretum at the Luquillo Experimental Forest are also being included in a genetic marker taxonomic survey of the Swietenoideae of the family Meliaceae (project headed by ITE, Scotland). The survey of wood density in the surviving trees of the Puerto Rican provenances has been completed for comparing the effects of environment and genetic background on this component of wood quality. A perspective on the causes and effects of shootborer attack in the early years of this provenance trial were presented at the North American Forestry Commission in Merida, Mexico, and has been submitted for publication.

The collaborative work funded by FAS with CATIE on genetic trials of *S. macrophylla* and *C. odorata* in Mexico and Costa Rica continue, with analysis of early measurements. Preliminary results of the *S. macrophylla* trials in Mexico were presented at a forest genetics conference this year in French Guiana. A study comparing quantitative traits in seedlings of *C. odorata* from ecologically distinct zones of Costa Rica has been submitted for publication. I assisted with the planning for the collection of *S. macrophylla* germ plasm completed in eastern Bolivia this summer by C. Navarro of CATIE in a joint project funded by FAS. This collection was part of a larger objective to complete the collection of germplasm of *Swietenia* from the ranges of the three species for purposes of genetic characterization (using genetic markers and quantitative traits), performance assessment, and conservation.

The history of U.S. Forest Service research at Estate Thomas, St. Croix, U.S.VI, was reviewed and presented at the Urban Forestry Conference in St. Croix. The proceedings are to be published (Ward and others 2000). I also provided the research component for the future planning for Estate Thomas.

Arranging the remeasurement data sets of the four hundred 0.089-ha plots that Frank Wadsworth established in the 1950's at the Luquillo Experimental Forest continues under UPR student Vanessa Rivera with funding from the NASA INRA program. GPS of representative plots has been obtained, and mapping of these plots is underway. The remeasurement data sets will provide information on forest dynamics that can be interpreted in relation to land use history and other spatial environmental variables for the mapped plots.

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FOREST RESEARCH

Peter L. Weaver
Research Forester

INTERNATIONAL COOPERATION

Mahogany in Nicaragua

Nicaragua's Indians, originally from Mexico and northern South America, were decimated by the Spanish soon after Columbus landed in 1502 (Weaver and Bauer 1999). By the 1530's, the new Spanish settlers were cutting mahogany along with other timbers for shipbuilding at Realejo [now Corinto] on the Pacific coast. By the 1600's, the Spanish occupied much of the Pacific coast, and the British exploited forest resources along the Caribbean coast. The major Meliaceae, big-leaf mahogany, Pacific coast mahogany, and Spanish cedar were selectively logged throughout the colonial period, a practice that continued during the 20th century when a few more species were added to the commercial harvest. Land clearing for agriculture also eliminated forest resources and reduced the major Meliaceae. Important agricultural activities included coffee plantations from the late 19th century through 1950 and cotton farming from 1950 through 1980, both in the Pacific region, and expansion of the agricultural frontier eastward toward the Caribbean coast from the 1970's to the present. Forest cover, occupying slightly more than 50 percent of the country in 1950, declined to 33 percent in 1990; it is estimated to be 25 percent for the year 2000. Big-leaf mahogany and Spanish cedar plantations occupy only about 20 ha, and forest management is limited to experimental work on only 15 ha. A total of 73 conservation areas cover nearly 17 percent of the entire country, and forest resources in these areas should remain protected. Currently, Pacific coast mahogany is listed in Appendix II and big-leaf mahogany in Appendix III of Nicaragua's Redbook of Endangered and Threatened Species.

Species Trials in the Dominican Republic

The growth and acclimatization of nine species (*Acacia mangium, Azadirachta indica, Catalpa longissima, Cedrela odorata, Eucalyptus grandis, Pinus caribaea, Simarouba glauca, Swietenia macrophylla, and S. mahagoni*) established either as line plantings or block plantations, were evaluated 18 to 44 months after planting in Tocoa, Dominican Republic (Sanchez 1999). Different methods of planting did not result in marked differences in growth except for *A. mangium* in dense, block plantations, (e.g., 2,667 trees per ha) where the initial rapid growth rate and density of the stand led to reduced diameter growth at an early age. The mean annual increment in height and diameter on the best sites were *A. mangium* (4.25 m and 3.95 cm), *E. grandis* (3.38 m and 2.54 cm), *S. macrophylla* (2.20 m and 2.31 cm), *S. mahagoni* (1.34 m and 1.26 cm), *A. indica* (2.06 m and 1.90 cm), and *S. glauca* (1.46 m and 1.57 cm). The mean annual increments in height of the poorly developed species were *P. caribaea* (0.23 m), *C. longissima* (0.81 m) and *C. odorata* (0.53 m). It is concluded that the growth of the nine species was influenced by soil conditions, maintenance practices (weed control, especially grasses), and the capacity of each species to adjust to extremely degraded soils. *Acacia mangium*, *E. grandis*, *S. glauca, S. macrophylla,* and *S. mahagoni* were the most promising species for reforestation under the conditions tested.

San Lorenzo Protected Area (SLPA), Panama

Fort Sherman, at the northwest entrance to the Panama Canal, reverted to the Panamanian Goverment at the end of June 2000. Currently, the International Cooperation program of the IITF is cooperating with USAID and CEASPA (a local NGO) in the preparation of a slide program and technical report on the SLPA. Both highlight the SLPA's setting as a major crossroad and briefly describe pre-Columbian activities, the Spanish conquest, the legacy of fortune seekers and the Chagres River, the building of the Panama Canal, and early agricultural activities. The military history of

both Fort San Lorenzo and Fort Sherman will be discussed along with current knowledge on the geology, soils, flora, fauna, marine resources, ecological research, and proposed conservation of the SLPA. A chronology of major historical events related to the SLPA will also be included.

RESEARCH

Elfin Woodland in Puerto Rico

Grasses and ferns characterized the recovery of elfin woodland for the first 18 years after a December 1968 airplane crash (Weaver 2000). From 1986 to 1998, ferns and woody dicots were prominent, and the total aboveground dry weight biomass increased from 775 to 2210 g/m^2. Woody dicots increased 3.5 times, palms 1.3 times, and ferns 4.4 times above their 1986 levels. Grasses and herbs decreased by nearly 10 percent. Recovery was patchy, with some areas dominated by trees ^{3}4 m in height and others by grasses and scattered ferns. Puerto Rican endemic trees are playing a critical role in the recovery of the elfin woodland and are prominent in mature elfin woodland as well. Endemics account for 88 to 94 percent of the woody dicot stems 18 to 30 years after the wreck, and from 55 to 72 percent of the stems in mature elfin woodland. The largest stems on the wreck site average about half of the typical heights and d.b.h.'s of mature elfin woodland trees and biomass are about a fourth of that found in mature elfin woodland. Species composition is similar. It is estimated that complete recovery will take almost two centuries.

Montane Rain Forest in Puerto Rico

Forest structure and species richness vary along environmental gradients in the colorado forest [montane rain forest] of Puerto Rico's Luquillo Mountains (Weaver 2000). Rainfall and temperature vary with aspect and elevation resulting in wetter conditions to the windward than to the leeward. A covariance model showed that: stem density increases significantly with elevation to the windward but not to the leeward; tree height decreases significantly with elevation on both windward and leeward exposures; total aboveground woody biomass decreases significantly with elevation on ridges to the windward; and organic matter increases significantly with elevation to the leeward. ANOVAs disclosed interactions between aspect and topography for species diversity and biomass. Species-area curves show the greatest number of species on ridges and the fewest in ravines.

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WILDLIFE RESEARCH

Joseph M. Wunderle, Jr.
Wildlife Team Leader & Research Wildlife Biologist

During FY-2000, I continued four studies, supported cooperative studies, and published the results of previous wildlife investigations. These activities are summarized below:

CURRENT FIELD PROJECTS AND REVIEWS

Effects of Low-Impact Logging on Birds and Bats of the Forest Understory of the Tapajós National Forest

Continental tropical forests are characterized by a high diversity of species, most of which are rare. Nowhere is this more evident than in the Amazon forests of Brazil, where our current collaborative studies with researchers from the Goeldi Museum and Dr. Michael Willig of Texas Tech University are helping to characterize the understory bird and bat assemblages in the Tapajós National Forest near Santarem. Our collaborative studies based on mist netting enable us to describe and characterize the avian and bat diversity in the forest understory, and more importantly, serve as a control for examining the effects of low-impact logging on these components of the fauna in an Amazon forest. Such studies are beneficial for devising tropical logging and silvicultural methods, which minimize biodiversity loss and ensure that animal seed dispersers remain on managed sites to provide adequate seed dispersal. Our current field study will end in June 2001.

Movements, Home Range, and Habitat Use by the Puerto Rican Boa in the Luquillo Experimental Forest

We are now in the fourth year of a study of the endangered Puerto Rican Boa (*Epicrates inornatus*) based on surgically-implanted radio transmitters, which enable us to use radio telemetry to locate and follow snakes in the LEF. The locations where the radio-tagged snakes are found by telemetry are mapped by the use of GPS, which enables us to quantify movements and determines the size of a boa's home range. The passage of Hurricane Georges in September 1998 appeared to have little or no effect on the five radio-tagged boas we were following at the time. Field work will continue until June 2001 to further document the natural history and movements of these snakes.

Phenology of Some Common Fruits Consumed by the Puerto Rican Parrot

We are now in the fourth year of a phenology study designed to monitor fruit production of the more common tree and vine species in the Palo Colorado forest of the LEF. The study involves monthly sampling of marked plants along trails at Camitillo (10 species; 122 individuals originally) and Palo Hueco (11 species, 144 individuals originally). The study is designed to characterize variation in fruit production to help understand the behavior of the Puerto Rican parrot to identify the most important time periods to release aviary-produced parrots.

Hurricane Georges struck the LEF in September 1998, just as we completed 2 years of phenology sampling, providing baseline for posthurricane comparisons. As we found previously in the aftermath of Hurricane Hugo, little fruit remained on the marked plants after the storm, and phenological patterns shifted out of phase from normal prehurricane patterns. We will continue to monthly monitor the recovery of fruit production at these sites.

A Review of the Puerto Rican Parrot and Its Recovery: 1973–2000

I am currently working with participants from the Puerto Rican parrot (*Amazona vittata*.) workshop and members of the recovery effort to summarize and evaluate the parrot's population growth, nesting success, survival, and the overall success of the recovery effort. This involves analyses of wild and captive data, much of which has never been summarized previously. The

goal of the project is to identify critical research needs and areas in which increased management intervention could increase population growth.

PUBLICATIONS

As part of our contribution to the recovery of the endangered Puerto Rican parrot, I published the results of a 5-year fruiting phenology study (Wunderle 1999b). In this work, I quantified fruit availability on 25 plant species consumed or potentially consumed by the Puerto Rican Parrot to document the seasonal and annual variation in fruit production in the Luquillo Mountains. In the 33 months before Hurricane Hugo, an annual cycle in the number of species with ripe fruit was evident, with a peak in October–February and a trough during June–July. About half the plant species showed this annual fruiting cycle. Irregular noncyclic fruiting was found in the other half and varied among species in annual duration. Fruit production reached its lowest point in October 1989, just after Hurricane Hugo, when 72 percent of the broadleaf foliage was lost and only one species had ripe fruit. The number of fruiting species subsequently increased, but the cyclic fruiting pattern, evident in the number of fruiting species before the storm, disappeared and was not observed during 27 months after the storm. This noncyclic pattern was attributed mostly to species with annual fruiting cycles in which annual fruiting shifted out of phase, was suppressed after the hurricane, or both. Parrot breeding was associated with fruiting, as breeding occurred during fruiting peaks before the storm, and was delayed in the first season after the storm, but returned to normal by the second season. Thus, parrots faced considerable annual and year-to-year variation in fruit availability prior to the hurricane, and substantial fruit loss afterwards followed by a recovery involving changes in fruiting phenology of individual species and the overall community.

As part of our studies on the role of traditional shade coffee plantations as potential refugia for forest-dwelling birds in deforested or degraded landscapes in the Tropics, we published two papers. I summarized the role of shade coffee plantations in conserving bird diversity in a presentation and publication for the Society of Caribbean Foresters (Wunderle 1999a). In addition, we published a paper on winter-site fidelity of Nearctic migrants in shade coffee plantations of different sizes in the Dominican Republic (Wunderle and Latta 2000). Here we studied three Nearctic migrant species (American redstart [*Setophaga ruticilla*], AMRE; black-and-white warbler [*Mniotilta varia*], BAWW; black-throated blue warbler [*Dendroica caerulescens*], BTBW) wintering in 14 isolated shade coffee plantations (0.1 to 8.7 ha) to determine if site fidelity in shade plantations was comparable to that in tropical forests and if it decreased with plantation size. Site fidelity was measured as the percentage of wandering birds captured in mist nets, as overwinter site persistence of uniquely marked birds observed on the same sites (November to March), and as the annual return of marked individuals to previously occupied sites (January to January). The percentages of wanderers in net captures were mostly lower than values reported for natural forests (AMRE 21 percent, BAWW 12 percent, BTBW 41 percent) and did not vary with plantation size. Overwinter site persistence (AMRE 65 percent, BAWW 65 percent, BTBW 76 percent) and annual return (AMRE, 34 percent; BAWW, 40 percent; BTBW, 31 percent) in the plantations fell within the range of values reported for natural forests. Overwinter site persistence decreased with plantation size only in AMRE, although BAWW showed lower persistence in small plantations from early to midwinter. Annual return decreased with plantation size only in AMRE. Despite diminished site fidelity in small plantations, these birds still showed some fidelity to small plantations, many smaller than the mean winter home range sizes.

Several minor publications also appeared in this period. For example, I provided brief summaries of hurricanes and wildlife, island exotics, and bird migration in the Caribbean (Wunderle 1999c) for a wildlife viewing guide. In addition, we published a brief review of the Puerto Rican parrot (Wiley and others 2000) in a parrot conservation review. Finally, as a member of the Conservation Committee of the American Ornithologists Union, we evaluated the Partners In Flight species prioritization scheme for North American birds (Beissinger and others 2000).

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STATE AND PRIVATE FORESTRY ACCOMPLISHMENTS IN PUERTO RICO

Robin Morgan
Silviculturist

Investment in State's Cooperative Programs

Programs	FY2000	FY2000	FY2001	FY2001	FY2001	FY2001
			Title II, V & VIII	Title II, V & VIII	Title IV	Title IV
	Federal (U.S.$)	State (U.S.$)	Federal estimate (U.S.$)	State estimate (U.S.$)	Federal estimate (U.S.$)	State estimate (U.S.$)
Forest health management	68,750	118,348	16,000	32,000	50,000	50,000
Volunteer fire assistance	14,400	14,400	14,400	14,400	50,000	50,000
Forest stewardship program	158,882	233,529	162,888	233,529		
Stewardship incentives program	0	0	0	0		
Forest legacy program	729,000	729,000	1,330,000	1,330,000		
Urban and community forestry	177,661	280,131	177,661	280,131		
Economic action program	123,705	166,809	123,705	166,809		
Forest resource and analysis program	0	0	0	0		
Natural resource conservation Education	18,000	120,480	18,000	120,480		
Total	1,378,388	2,260,697	1,966,639	2,495,218		

The cooperative programs are administered and implemented through a partnership between the Government of Puerto Rico, the U.S. Department of Agriculture, Forest Service, and many other private and government entities. Emphasis focuses on agroforestry, timber and other forest products, wildlife, water resources, rural economies, and conservation practices. The goal is to maintain and improve the health of Puerto Rico's urban and rural forests and related economies. These programs:

- reduce costs through the use of partnerships;
- increase values through sustained productivity of forests; and
- are voluntary and nonregulatory in their delivery.

Puerto Rico has almost 700,000 acres of privately owned forest land and 28,000 acres of national forests. Of the 368,668 individuals owning forest lands, most have parcels less than 20 acres in size. Almost all of these landowners report that conservation, esthetic enjoyment, and recreation are primary reasons for owning forest land. The State's 3.9 million people include 78 municipalities (approximately 274 communities) with populations over 100; all of these have initiated some level of community forestry program.

Key Issues

Key issues, which the State will address with the 2001 budget include:

- protection and restoration of natural areas;

Forest Facts and Accomplishments

Selected facts		Selected results	
Population	3.9 million	Stewaardship plans prepared (current year)	25
Population density, people per square mile	1,000 people	Area under stewardship plans (current year)	449 acres
People per square mile, San Juan metro area	20,000 people	Area under stewardship plans (all years)	3,438 acres
Tree species on the island, number	570	Rural acres planted	3,895 acres
Exotic or naturalized tree species, number	225–250	Technical assists to private landowners	1,344
Extent of protected lands	< 5%	Rural fire districts assisted	N/A
Miles of roads per square mile	4 miles	Rural fire department volunteers trained	N/A
Acres of forest land	709,177 acres	Acres surveyed for forest health	55,723 acres
Acres of nonindustrial private forest land	689,409 acres	Forest health assistance visits	140
Number of NIPF landowners	368,668	Communities assisted	274
Acres of land use under state fire protection	2,226,400 acres	Economic action grants to rural areas	7
Number of municipalities	78	Technology transfer and workshops	4,289 days
State forestry budget	$13,686,000	Acres protected through acres program	529 acres

- soil protection and watershed management;
- sustainable urban forestry programs at the local level;
- creation of jobs and income utilizing natural resource based opportunities.

PROGRAM HIGHLIGHTS

Forest Health Protection
Prominent forest health problems identified in a survey of State forest lands include: hurricane damage, construction pressure, and general insects and disease. Planning for periodic (vs. annualized) FIA was conducted with the PR DNR, and implementation of the Urban Forest Effects Model as part of FIA was planned and budgeted in the 2000 annual budget.

Cooperative Fire Protection
Development of a Wildfire Assessment was begun, overlaying the mapped history of wildlife on the island (risk) with fuel types (hazard) and structures (value). The assessment will not be utilized in future resource placement and training.

Forest Stewardship
Hispanic landowners numbering 1,360 have become active in reforestation and management activities on privately owned forest land. A watershed approach was taken this past year in that an NRCS-rated priority watershed received focused technical assistance for the development of landowner plans for adjacent properties along the river's edge. The management plans together form the basis for a subwatershed management approach, and the landowners form a coalition for management of the land as a landscape verses individual parcels.

Forest Legacy
The priorities for protection are: to conserve and restore forested watersheds, which are the island's primary water supply; buffer zones of existing forest reserves, natural reserves, and wildlife refuges; conserve forested areas in primary or close to primary conditions; and conserve bio-diversity and unique features. Five hundred twenty-nine acres were acquired fee simple in the Guanica Legacy Area. In an effort to promote the Forest Legacy Program, promotional materials were developed, a landowner survey was conducted, and contact was made with landowners in each of the forest legacy areas.

Urban and Community Forestry
A major reforestation program was undertaken by the central government in Puerto Rico in collaboration with many partners. Community action in the planting and care of trees in urban areas was effectively conducted in every municipality on the island and involved over 19,000 volunteers.

Economic Action
A very strong ecotourism network and local community planning have been facilitated through the RCA programs. Support for sustainable management of rural natural resources has been increased through Rural Community Assistance projects focused on ecotourism, planting, and development.

Natural Resource Conservation Education
An ambitious educational component has been developed that offers to the participants printed materials written in Spanish (fact sheets and a manual for school children), planting materials, and the technical and organizational assistance for school planting projects. In addition, there are six high schools implementing an education reform.

STATE AND PRIVATE FORESTRY ACCOMPLISHMENTS IN THE U.S.VI

Robin Morgan
Silviculturist

Investment in State's Cooperative Programs

Programs	FY2000	FY2000	FY2001	FY2001	FY2001	FY2001
			Title II, V & VIII	Title II, V & VIII	Title IV	Title IV
	Federal (U.S.$)	State (U.S.$)	Federal estimate (U.S.$)	State estimate (U.S.$)	Federal estimate (U.S.$)	State estimate (U.S.$)
Forest health management	0	0	15,000	15,000		
Forest health monitoring	0	0	20,000	0		
State fire assistance	70,000	70,000	70,000	70,000	27,000	27,000
Volunteer fire assistance	9,000	9,000	9,000	9,000	21,000	21,000
Forest stewardship program	60,000	60,000	60,000	60,000		
Stewardship incentives program	0	0	0	0		
Forestry legacy program	0	0	50,000	50,000		
Urban and community forestry	138,000	138,000	138,000	138,000		
Economic action program	0	0	10,000	10,000		
Forest resource information and analysis	0	0	0	0		
Natural resource conservation education	8,000	8,000	8,000	8,000		
Total	285,000	285,000	380,000	360,000		

The cooperative programs are administered and implemented through a partnership between the U.S. Virgin Islands, the U.S. Department of Agriculture, Forest Service, and many other private and government entities. These programs promote the health and productivity of the Virgin Island's forest lands and rural economies. Emphasis focuses on agroforestry and other forest products, wildlife, water resources, rural economies, and conservation practices. The goal is to maintain and improve the health of the Virgin Islands' urban and rural forests and related economies. These programs:

- reduce costs through the use of partnerships;
- increase values through sustained productivity of forests; and
- are voluntary and nonregulatory in their delivery.

U.S.VI has 21,702.73 acres of privately owned forest land and 140 acres of experimental forest. Of the 1,000 individuals owning forest lands, most have parcels less than 20 acres in size. Almost all of these landowners report that agriculture and aesthetics are primary reasons for owning forest land. The State's 112,863 people include 46 communities with populations over 100; 41 percent of these have initiated some level of community forestry program.

Forest Facts and Accomplishments

Selected facts		Selected results	
Population (1997)	112,863	Stewardship plans prepared (current year)	12
Acres of forest land	21,702	Area under stewardship plans (current year)	428
Acres of nonindustrial private forest land	13,824	Area under stewardship plans (all years)	428
Number of NIPF landowners, estimated	1,000	Rural acres planted	3
Acres of Federal land under State fire protection	7,500	Technical assists to private landowners	16
Acres of private land under State fire protection	13,824	Acres surveyed for forest health	13,824
Number of communities	46	Forest health assistance visits	20
State forestry budget	$217,000	Communities assisted	46
		Technology transfer and workshops (days)	150

Key Issues

Key issues, which the State will address with the 2001 budget, include:

- ecological restoration of natural and built-up areas;
- soil protection and watershed management;
- sustainable urban forestry programs; and
- creation of jobs and income utilizing natural resource-based opportunities.

PROGRAM HIGHLIGHTS

Forest Health Protection

The pink hibiscus mealybug has infested all lands in the U.S. Virgin Islands (St. Croix, St. Thomas, and St. John). Damage was also reported from bark beetles, aphids, white flies, caterpillars, wilt, shoot borers, hurricanes, and construction stress. The Department of Agriculture is working closely with the University of the Virgin Islands to assess the forest health of all forest communities in the islands.

Cooperative Fire Protection

The entire territory can be classified as an urban/wildland interface. There are very few rivers, no lakes, and limited number of fire hydrants in these islands' environment. Variable trade winds, fuel build up associated with dry tropical forests, narrow and steep roads, and difficult building entrances all combine to create a wildfire challenge. The VI Fire Service is working with the VI Department of Agriculture and the Cooperative

Extension Service to prepare a wildlife protection assessment.

Forest Stewardship
Matching natural resource professionals with farmers and other landowners is expanding the vision of forest stewardship opportunities in the U.S.VI. Recognizing the importance of protecting habitat for wildlife, soil for water quality, and aesthetics for tourism and economic development changes the way people view their responsibility to utilize the opportunities for maintaining a healthier island.

Urban and Community Forestry
The urban and community forestry assistance is well positioned to confer benefits to the people of the Virgin Islands. The program inspires hope in the community through the activities of grant subrecipients and motivated citizens. The traditional tendency to top trees at the approach of a hurricane is deep rooted. This program seeks to address these concerns at the local level by offering training opportunities and technical assistance in proper tree management.

Economic Action
The VI Resource Conservation and Development Council is an active partner in delivering this program. Supporting the existing resources for helping present and newly developed business, the VI RC&D Council strives to enhance job and income opportunities, which utilize the islands' natural resources.

Natural Resource Conservation Education
The VI ReLeaf program addresses the territory's need for new tree planting, tree care information, and education. Lack of an organized governmental tree-care policy and land use planning leads to tree removal without replacement and improper and neglected tree care on public lands. VI ReLeaf provides trees for schools and reaches at least 2,000 students annually. The "Trees for Schools" program teaches students the benefits of trees and proper tree care, thus encouraging greater pride in their schools and in their islands.

INTERNATIONAL COOPERATION HIGHLIGHTS

Carleen Yocum
Caribbean Environmental Advisor

During the course of fiscal year 2000, the International Cooperation (IC) unit of the IITF was involved in many projects of benefit to a variety of individuals and organizations in many countries. Some of the major highlights of this year follow:

- Developed an agreement with FAO (Food and Agriculture Organization of the United Nations) for participation in delivering a training course in Management of Secondary Forests, held in April in Dominica.

- Continued to work in Hurricane Georges Reconstruction Program in the Dominican Republic. A U.S. $410,000 Inter-Agency Agreement (IAA) with USAID/WO (United States Agency for International Development, Washington Office) was formalized, and the first portion of money transferred to the IITF. This IAA enabled, among other things, the sponsorship of 14 Dominicans to an urban forestry workshop at the University of Puerto Rico at Mayaguez. Also of note during this term was the assistance of four Forest Service short-term detailers that provided technical assistance to Dominican counterparts in wildfire reconnaissance, firefighting organization and actual suppression, and timber salvaging. A report was prepared in English and translated into Spanish regarding the latter subject to serve as a case study for future timber salvaging operations in developing countries in the face of natural disasters such as hurricanes.

- Developed agreements with FAO and Puerto Rico Conservation Foundation for preparations of the 10th Caribbean Foresters Meeting. This meeting was held June 13–16, 2000, in Guyana. The theme for this year's meeting was Possibilities and Approaches to Community Forestry in the Caribbean. There was representation from 14 countries and a total of 54 participants. IC received requests, and the library distributed approximately 167 publications to 25 participants of the meeting.

- IC published, and the IITF library distributed, the proceedings of the ninth Caribbean Foresters meeting, which was held in the Dominican Republic in 1998.

- A U.S. Department of Agriculture, Forest Service, IITF employee, assigned to the IC unit and stationed in Panama, facilitated the transfer of the canal, and continues to work on watershed issues of this zone as well as protected areas management. Also of note was the development of a signage and interpretation plan for one of the national parks; partnership development; production of a research paper for the San Lorenzo protected area; development of a mahogany line planting study plan; management of the AID/Panama environmental portfolio; technical assistance to the Nicaragua Mission; one-day workshop for 70 counterparts on the development of signage plans for national parks; assistance to a local NGO in preparing a proposal for conservation training for journalists; assistance to a local NGO in developing a proposal for an environmental education program; providing technical assistance to develop a national campaign for conservation for the Panama Canal watershed; and conducting an agroforestry assessment of the AID/Panama program.

- The IC unit received funds from USAID to fund followup activities to the low impact logging training conducted by the Tropical Forest Foundation in Brazil for Guyanese participants held in November 1999.

- Awarded and managed a U.S. $72,000 contract for the study for increasing marketing opportunities of lesser-known wood species and secondary wood

products in Central America and Mexico. During the fiscal year, this contract produced a report in Spanish regarding the production potential of small-diameter trees in Quintana Roo, Mexico.

- IC performed a field review and generated a full report for an evaluation of the forest concessions portion of the AID-funded Maya Biosphere Reserve Project, managed in Guatemala. The report is titled, 1999 Review of Forest Management in Cooperatives and Community Concessions in the Maya Biosphere Reserve.

- Completed analysis and input to FAO's Global Resource Assessment 2000, and participated in related meeting in Trinidad.

- Participated in a workshop in Honduras for environmental considerations in designing rural roads.

- Performed an evaluation for USAID/Nicaragua of the national forestry agency and developed possible alternatives for collaboration with the U.S. Department of Agriculture, Forest Service, and other opportunities for AID assistance.

- Developed possible options for resolving the Vieques Island land issue.

APPENDIX 1: ANNUAL LETTER 1999-2000 PUBLICATIONS LIST

A. Recent publications of the International Institute of Tropical Forestry (Numbers indicate reprints available for distribution).

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