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International Institute
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General Technical
Report
IITF-GTR-29
October 2005

Annual Letter 2001-2002

Cover

The cover is based on a drawing by W. Ellis Groben, Forest Service architect. He designed several Forest Service buildings including the one for the International Institute of Tropical Forestry. It depicts the front of the building from the northwest end.

Annual Letter 2001-2002

U.S. Department of Agriculture

Forest Service

International Institute of Tropical Forestry

San Juan, Puerto Rico 00926-1119

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Contents

Comparing Aboveground Biomass Equations for Use With the Puerto Rico Forest Inventory Data

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Introduction

The USDA Forest Service's Southern Research Station Forest Inventory and Analysis (FIA) Program and International Institute of Tropical Forestry (IITF) planned to complete field data collection for a forest inventory of the island of Puerto Rico by midyear 2003. These data will be supplemented with plots in forest types underrepresented in the standard FIA sampling grid. This forest inventory will be the most complete in the island's history.

Forest inventories traditionally include estimates of the volume of merchantable wood fiber. Examination of Puerto Rico's forest productivity and its role in global biogeochemical cycles also requires the estimation of forest aboveground biomass (AGB) for individual live trees. Therefore, an important part of forest inventory data analysis is the use of volume tables, geometric equations, or regression equations that convert tree measurements such as diameter at breast height (D_{bh} at 1.37 m) and total tree height (H_T) to some measure of wood volume or biomass. These tables and equations are developed in detailed stem analysis and biomass studies, and in general, those developed for specific locales, forest types, or species tend to be more accurate than generalized tables and equations.

This work has been done for most of the major timber species in North America, but not for many of the tropical forests. In Puerto Rico, regression equations that predict AGB have been developed for the forests of the Luquillo Mountains owing to the presence of the Caribbean National Forest, but not for many of the other forest types that are being currently inventoried on the island. General regression equations developed from data sets collected in many tropical forests, such as those in Brown (1997) and Brown et al. (1989), can be used where locally developed equations are lacking. However, locally developed AGB regression equations should give superior estimates.

To overcome this problem in previous forest inventories, detailed measurements were taken of each tree over 12.5 cm D_{bh} to allow the use of a generic tree volume formula, Smalian's equation (Birdsey and Weaver 1982, 1987; Franco et al. 1997). Merchantable tree volumes (presented in ft^3 of green wood) available by forest type and species could then be calculated (Birdsey and Weaver 1982, 1987; Franco et al. 1997). The AGB for stems and large branches was estimated by multiplying the merchantable volume estimate by an expansion factor. This approach gave good estimates of merchantable stem volume for forests where local volume tables and equations are still lacking.

However, replicating these calculations with the present inventory data is not possible. The current inventory follows the new field data collection protocols being implemented by FIA across the continental United States, the Caribbean, and the Pacific Islands. Fewer measurements that could be used to estimate volume are taken on each tree, and some of those needed for Smalian's equation are not included.

Estimating AGB from the current inventory data requires another approach. I propose examining the general regression equations given in Brown (1997) and Brown et al. (1989) that predict AGB from individual tree measurements (D_{bh} and H_T), and compare their estimates of AGB with estimates from local AGB equations and published AGB estimates for forests on the island.

Methods

To select the appropriate local AGB equations, I reviewed the literature and concentrated on studies that produced regression equations of the relationship between D_{bh}, H_T, and individual tree AGB. Puerto Rico's forest inventory data will have D_{bh} and H_T for all tree species with D_{bh} >12.5 cm (total sampled area at each inventory point = 0.067 ha), and all saplings with D_{bh} >2.5 cm that fall within the nested microplots (total area of microplots per subplot cluster = 50.3 m^2).

There are two test data sets. The first data set is the 1990 forest inventory results. These data were collected on 167 forested plots in the Holdridge subtropical moist and wet life zones (see Ewell and Whitmore 1973 for details). The second data set comes from 25 forested plots measured in a forest health monitoring pilot study in 2001, and the 1990 inventory data. The 2001 plots were also categorized according to Holdridge life zones; 3 plots fell in subtropical dry forest, 15 in subtropical moist forest, and 7 in subtropical wet forest.

Brown et al. (1989), and the updated Brown (1997), presented regression equations for total AGB kilograms per tree) for three tropical Holdridge life zones, dry, moist and wet-based on nine tropical forest data sets (wet forest data from Puerto Rico was one data set). The models were extrapolated up to 300 cm D_{bh}. The only locally developed equations examined here come from studies in the Luquillo Mountains, and are for forests in the subtropical wet Holdridge life zone.

The 2001 data set was analyzed by using the equations that corresponded to the appropriate life zone. The 1990 data set was analyzed by using general and local equations for both subtropical moist and wet forests (equations 3-10).

Subtropical dry forest

$AGB = \exp\{-1.996 + 2.32 \ln[D_{bh}]\}$	(Brown 1997)	(1)
$AGB = 34.4703 – 8.0671 (D_{bh}) + 0.6589 (D_{bh}^2)$	(Brown et al. 1989)	(2)

Where

AGB = total aboveground biomass, in oven-dry kilograms

D_{bh} = stem diameter in cm at 1.37 m.

Subtropical moist forest

$AGB = 42.69 – 12.800(D_{bh}) + 1.242(D_{bh}^2)$	(Brown 1997)	(3)
$AGB = \exp\{-2.134 + 2.530 \ln[D_{bh}]\}$	(Brown 1997)	(4)
$AGB = \exp\{-3.1141 + 0.9719 \ln[D_{bh}^2 H_t]\}$	(Brown et al. 1989)	(5)

Where

H_t = total tree height in meters

Subtropical wet forest

$AGB = 21.297 – 6.953(D_{bh}) + 0.740(D_{bh}^2)$	(Brown 1997)	(6)
$AGB = \exp\{-3.3012 + 0.9439 \ln[D_{bh}^2 H_t]\}$	(Brown et al. 1989)	(7)
$AGB = \exp\{0.950 \ln[D_{bh}^2 H_t] – 3.282\}$	(Scatena et al. 1993)	(8)
$AGB = -0.1106 + 0.02991(D_{bh}^2 H_t)$	(Weaver and Gillespie 1992)	(9)
$AGB = 1.3145 + 0.03023 (D_{bh}^2 H_t)$	(Weaver and Gillespie 1992)	(10)

All of the above equations produce individual tree AGB estimates in kilograms (ovendry weight). These individual tree estimates were then expanded to megagrams per hectare of AGB. Estimates are for woody vegetation classed as trees according to FIA definitions, with stems of D_{bh} ≥2.5 cm. Shrubs are not included in the inventory data.

Results

Estimated AGB values for each forest life zone are presented in table 1. Analysis of variance indicated that the AGB estimates for dry, moist, and wet life zones made with the 2001 inventory data were not significantly different (alpha level = 0.05).

Table 1—Mean AGB (megagrams per hectare ovendry weight), standard errors, maximum and minimum plot values, for subtropical dry, moist and wet forests

Equation	Mean AGB (SE)	Maximum	Minimum
Subtropical dry			
2001 data			
1	2.89 (2.50)	23.55	0.67
2	35.41 (31.55)	98.47	1.82
Subtropical moist			
2001 data			
3	161.94 (42.61)	707.94	24.38
4	136.66 (45.44)	753.03	19.80
5	84.43 (20.50)	344.20	14.65
1990 data			
3	150.13 (7.181)	445.20	6.81
4	122.24 (6.509)	361.26	.15
5	80.05 (5.007)	274.41	.11
Subtropical wet			
2001 data			
6	130.54 (43.27)	292.47	25.92
7	75.14 (25.06)	165.32	12.12
8	81.34 (27.29)	179.93	12.96
9	106.30 (37.43)	245.46	15.29
10	110.05 (37.84)	248.98	16.19
1990 data			
6	90.332 (4.424)	272.108	3.139
7	51.473 (3.161)	174.061	.093
8	55.450 (3.419)	188.094	.093
9	69.534 (4.443)	242.668	.008
10	73.369 (4.533)	251.633	.945

Note: equation numbers correspond to numbering in the methods section.

Discussion

First, the variability in the data must be noted. Standard errors, and the maximum and minimum mean AGB estimates show the wide range of variability encountered in the forests of Puerto Rico. This is to be expected given the long history of land use and forest disturbance across the island. The low minimum values are particularly interesting and may indicate the need to remove outlying points, e.g., plots that were only partially forested or highly disturbed, if meaningful estimates for each forest type are to be made. The 1990 data included plots that were classified as "reversions" from agricultural land to forest and may have still been highly understocked. Forest Inventory and Analysis uses a minimum value of 10 percent normal stocking, which has been changed for Puerto Rico to 10 percent canopy coverage in trees. The decision to classify an inventory point as forested (measured) or nonforested (not measured) rests with the field crew and is subjective. Additional analysis with and without less-stocked plots might reduce this variation.

There are striking differences between the AGB estimates made with the different equations. Equations that incorporate total tree height consistently gave lower AGB estimates for Puerto Rico's moist and wet forests. This may be due to the shorter stature of the island's hurricane-exposed forests when compared to continental forests where most of the data used to generate these equations were collected.[1]

The equations from Brown et al. (1989) that incorporated tree height more closely approximated the estimates coming from local AGB equations for wet forest with the 1990 data. Variability was too high in the 2001 data to make this assessment, although there is an indication that this may hold true also. Further testing with the complete data set (165 forested plots projected) will be necessary before a final decision can be made on which regression equations are best for estimating AGB in Puerto Rico's subtropical wet forests.

To further evaluate regression equation estimates, comparison can be made to AGB values found in several studies in comparable forests where the standing AGB was calculated for the same tree size classes (table 2). All values for moist and wet forests come from studies in the Luquillo Mountains. The estimates of mean AGB for wet forests calculated from the inventory data were appreciably lower than those of published studies. However, the published values fall within the range of maximum and minimum calculated means. This might indicate that

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[1]Helmer, E. 1999. Personal communication. Ecologist, International Institute of Tropical Forestry, Jardín Botánico Sur, 1201 Calle Ceiba, San Juan, PR 00926-1119.

Table 2—Total woody aboveground biomass estimates (megagrams per hectare) for forest types of Puerto Rico

Authority	Location	Forest type	Holdridge Life zone	AGB
				Mg/ha
Ovington and Olson 1970	Luquillo	Tabonuco	Subtropical wet forest	198.12
Frangi and Lugo 1985	Luquillo	Palm	Subtropical lower montane wet forest and rain forest	174
Weaver et al. 1986	Luquillo	Dwarf	Subtropical lower montane rain forest	48-110
Weaver 1987	Luquillo	Palo colorado	Subtropical lower montane wet forest and rain forest	121-145 130
Weaver 1990	Luquillo	Dwarf	Subtropical lower montane rain forest	332.6
Weaver and Murphy 1990	Luquillo	Palo colorado	Subtropical lower montane wet forest	130
Scatena et al. 1993	Luquillo	Tabonuco	Subtropical wet forest	110.3-221
Weaver 1998	Luquillo	Tabonuco, palo colorado, and palm	Subtropical wet forest, rain forest, and lower montane wet forest	232-285
Weaver 2000	Luquillo	Palo colorado	Subtropical lower montane wet forest	148.2
Murphy and Lugo 1986	Guanica	Dry forest	Subtropical dry forest	16.0

wet forests outside the protected national forest in the Luquillo Mountains may have significantly less AGB owing to their disturbance history. The differences between protected public forests and private forests are seen when basal areas are examined. Studies in the Bisley Experimental Watershed of the Caribbean National Forest where the Scatena et al. (1993) equation was developed found basal areas of 22.52 to 28.02 m^2/ha (Dallmeier et al. 1998). In inventory plots outside of public forests, Birdsey and Weaver (1982) found 13.8 m^2/ha basal area on wet and moist forest in 1980, and Franco et al. (1997) found 15.1 m^2/ha in 1990. Inventory plots from 2001 averaged 16.79 m^2/ha in the wet forest and 11.98 m^2/ha in moist forest.

The very low AGB estimate for dry forest in inventory plots when compared to Murphy and Lugo's (1986) estimate may also be the result of inventory plots falling in disturbed, degraded areas outside of the public forests. Murphy and Lugo (1986) estimated there to be 12,000 live trees (≥2.5 cm d.b.h.) per hectare and basal area of 21.2 m^2/ha on their study plots in the protected Guanica State Forest, whereas there was an average of 193 trees per hectare with basal area of 0.5 m^2/ha on the inventory plots. This difference in woody stem density may also result from the exclusion of shrubs from inventory data. Shrub exclusion will contribute to underestimating AGB, particularly in Puerto Rico's dry forest where shrubs are an important component of the vegetation.

Conclusions

Final decision on which regression equations to use for AGB prediction will have to be based on the full inventory data set. If the results for subtropical wet forest are taken as an indication, general equations that include total tree height, such as those in Brown et al. (1989), should be used where local AGB equations are not available. Otherwise, AGB for Puerto Rico's forests might be over estimated. Also, because of the disturbed nature of Puerto Rico's forests outside of the public forests, we should expect AGB estimates that are significantly lower than those found in previous studies exclusively limited to protected areas.

English Equivalents

When you know:	Multiply by:	To get:
Centimeters (cm)	0.394	Inches
Meters (m)	3.28	Feet
Hectares (ha)	2.47	Acres
Square meters (m^2)	10.76	Square feet
Trees per hectare	.405	Trees per acre
Kilograms (kg)	2.205	Pounds
Megagrams per hectare (Mg/ha)	.446	Tons per acre
Square meters per hectare (m^2/ha)	4.37	Square feet per acre

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Forest Conservation and Land Development in Puerto Rico

Eileen H. Helmer,
Ecologist

Rapid land use changes in Puerto Rico over the past century call into question how locations of land-cover conversion to urban/built-up lands relate to forests or reserved lands. A recent study (Helmer, n.d.) summarized island-wide land-cover change between 1977-78 and 1991-92 by using maps from Ramos and Lugo (1994) and Helmer et al. (in press). It also quantified, by ecological zone, land development, reserve protection, and forest cover. Finally, the study examined what landscape conditions favor land development, and whether simple forest cover attributes, reserve locations, or existing land cover influence where land development occurs.

Statistical modeling indicated that land-cover conversion to urban/built-up lands occurs most frequently near roads and existing urban areas, at lower elevations, and on more level terrain. Pasture is also more likely to undergo land development than other land covers. Land development is commonly associated with these attributes in most landscapes. The net result in Puerto Rico, however, is that most land development occurs in moist ecological zones with alluvial, volcanic, or sedimentary substrates or in dry areas with alluvial soils. Unfortunately, relatively tiny proportions of these same ecological zones or their upland forests received protection. Other landscape attributes such as amount of canopy cover of forests, forest patch size, and proximity to reserves do not affect where land development occurs. The results indicate that forests outside strictly protected boundaries are subject to land development's own socioeconomic path, regardless of forest condition. Consequently, opportunities to address ecological zone gaps in the island's forest reserve system, particularly at lower elevations, will be lost sooner in those zones that are relatively underprotected.

A major problem resulting from rapid land development at lower elevations is loss of wildlife habitat, which in turn destroys connectivity with montane reserve areas. Ample evidence demonstrates that many Puerto Rican species require a range of elevational habitats for resource or breeding purposes, including posthurricane refugia (Covich and McDowell 1996; Scatena and Johnson 2001; Wunderle, in press).

Assuming landuse allocation principles continue to favor land development or forest recovery over agriculture and pasture lands, Puerto Rico has a window of opportunity to conserve, restore, or strategically manage ecosystem functions and attributes in lowland areas.

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Soil Biology/Ecology Studies

Grizelle González,
Research Ecologist

Most of my research has been focused on the effects of soil organisms on ecosystem processes and functioning, as related to study plan 2566. In addition, three new research initiatives have been developed.

Soil fauna, microbes, and ecosystem properties along an elevation and climatic gradient in eastern Puerto Rico

In 2001, IITF scientists established and extensively monitored a network of 24 research sites (encompassing 8 different forest types). These sites are in mature forested areas in and outside the Luquillo Experimental Forest. Scientists measured climate, litterfall (quantity and quality), soil physical and chemical properties, and soil microarthropod abundances (from pitfall trapping) on a monthly basis. They also identified and measured trees and understory vegetation, and their height and diameter at breast height.

Preliminary results on the vegetation patterns showed that the average number of species within the 10 x 10 plots in the different forest types ranges from 3 species in the mangrove forest to 35.44 in the tabonuco forest. All forest types had a high percentage (between 88 and 100 percent) of native species. There are less than 3 percent nonnative species in all forests. The number of native species fluctuates between 22 and 35 for all the forests except the *Pterocarpus* and the mangrove forests, which have fewer than 8 native species. The highest percentage of introduced species occurs in the lowland moist forest with 8.5. There were no introduced species in the palm, *Pterocarpus*, and mangrove forests. Preliminary results along with a detailed description of methodology used in vegetation descriptions of these sites can be found in Carrero et al. 2002 and Gould et al. 2002.

Temperature data along the elevational gradient show higher monthly temperatures in sites below 200 m above sea level than in sites above 200 m in elevation (fig. 1). All sites showed a similar pattern of temperature seasonality between July 2001 and September 2002. The hottest period in 2002 was between June and September, and the coolest period was between January and February (fig. 1).

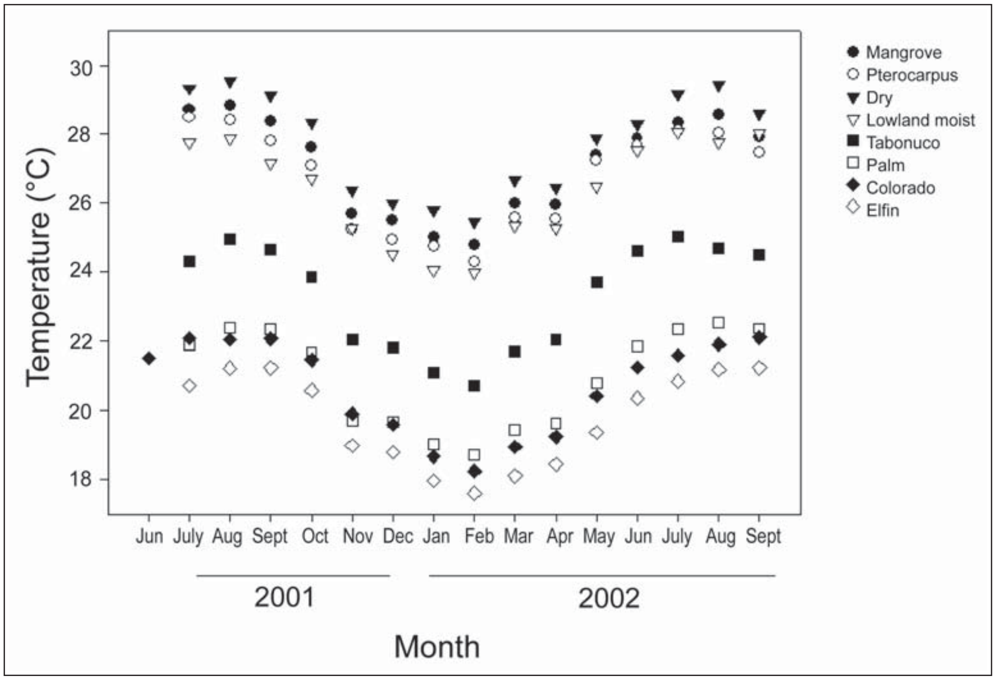

Figure 1—Preliminary results of mean monthly temperature (°C) of mangrove, *Pterocarpus*, dry, lowland moist, tabonuco, palm, colorado, and elfin forests (n = 3 for each) along an elevational gradient in eastern Puerto Rico.

Decomposition Experiment

Scientists from IITF in cooperation with the Joint Fire Science Program are studying fuel accumulation in fragmented landscapes in the different ecosystems across our national lands from tropical to boreal forests. The study includes sites that have a longer history of fire research (Alaska and Idaho) as well as sites where fires are common but their importance has not been well recognized (Puerto Rico). We will be studying the edge effect on fuel loads and wood decomposition in young and old, moist and dry forest fragments along the climatic gradient to better model and map fuel loads in fragmented forested ecosystems. The project combines efforts with two other Forest Service research facilities: the Rocky Mountain Research Station Laboratory in Idaho and the Boreal Ecology Cooperative Research Unit in Alaska. Two of these sites share research locations with two Long Term Ecological Research (LTER) sites: Bonanza Creek and Luquillo Experimental Forest (LUQ). This is the first fire ecology project related to and funded by the Forest Service in Puerto Rico. For more information about this project go to http://www.fs.fed.us/global/iitf/news.html.

The major objective of the decomposition portion of this project is to determine the effects of fragmentation on wood decomposition rates as related to fragment size, forest age, and climate at the macro and micro scales. Dowels of aspen wood will be placed in Alaska, Idaho, and Puerto Rico in sites that represent moist and dry fragmented forests of different sizes. The wood dowels will be placed in the center, the edge, and outside of the forest edge of a particular fragment. Four main hypotheses are:

- Decay rates will be higher at the forest edge than in the center of the forest fragment.
- Differences between decay rates of edges and centers will be greater as the fragment size increases.
- Differences between decay rates of edges and centers will be greater in older forests than in younger ones.
- Edges will have a stronger effect on decay at the sites with intermediate climate.

Invertebrate Manipulation in the Canopy Trimming Experiment—(LTER)

The canopy trimming experiment is part of a research program proposed by LUQ–LTER 3. The purpose of the experiment is to determine effects of repeated disturbance of the forest canopy and increased detrital inputs to the forest floor on germination, growth, survival, nutrient cycling, soil conditions, and trophic structure. The primary effect of the treatments will be to decouple the effects of canopy disturbance (e.g., light levels, temperature, and moisture) from the effects of detrital inputs on rates of detrital processing and community and ecosystem processes. Canopy disturbances will be repeated at 4-year intervals to look at the impact of an increased rate of hurricane disturbance on tropical wet forest ecosystems. In the short term, I will use the experiment to measure the effect of soil organisms on decay and nutrient mineralization in the context of hurricane-like disturbance. I will exclude micro- and macrofauna from the soil and litter layers to determine the relative contribution of different groups of the soil fauna on these ecosystem processes. In general, I hypothesize that the absence of invertebrate fauna will have strong effects on detrital dynamics, retarding decomposition rates and related processes. Microclimatic changes associated with canopy opening will reinforce these effects, but the addition of detritus will buffer the effects of canopy opening.

Population and Species Management Group: Effects of Exotic Species on Native Insular Biota—Decomposition and Nutrient Mineralization in Pig and Goat Exclusion Plots on Mona Island, Puerto Rico

This research effort looks at excluding exotic feral ungulates on Mona Island to determine (1) the effect of exotic species on island native biota and (2) the management implications of the eradication of exotics to native insular biota.

We will combine periodic field surveys of plant and animal diversity, large-scale use of herbivore exclosures, and laboratory plant and soil analysis to address questions aimed at characterizing the potential controls by mammalian herbivory on the depression forests. I will collaborate with researchers from the Puerto Rico Department of Natural Resources and Environment, and the University of Puerto Rico in the development of a soil biology/biogeochemical component of the study that looks at the effects of exotic biota on the nutrient cycling of the island dry forests.

English Equivalents

When you know:	Multiply by:	To get:
Meters (m)	3.28	Feet

Additional Accomplishments

Presentations

González, G. 2002. Effects of fragment size, age and climate on fuel loads and decay rates. Presentation at workshop on forest fragmentation and fuel loads, Moscow, Idaho, March (oral).

González, G. 2002. Landscape fragmentation and forest fuel accumulation: effects of fragment size, age and climate–a decomposition experiment. Presentation at International Institute of Tropical Forestry Science Seminar Series, Rio Piedras, PR, April (oral).

González, G. 2002. Preliminary results on soils along a climatic gradient in eastern Puerto Rico. Presentation at the LTER annual meeting, San Juan, PR, January (oral).

González, G. 2002. Soil organisms and plant litter decomposition. Presentation at the Long Term Ecological Research (LTER) annual meeting, San Juan, PR, January (oral).

Course Taught

A series of seminars on the biology, ecology and nutrient cycling of arctic soils. 2002. Course: EEB 4852 through the University of Minnesota and biocomplexity grant to University of Alaska-Fairbanks, Alaska, June-July.

Publications

González, G. 2002. Soil organisms and litter decomposition. In: Ambasht, R.S.; Ambasht, N.K., eds. Modern trends in applied terrestrial ecology. New York: Kluwer Academic/Plenum Press: 315-329.

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Research and Teaching in Landscape and Vegetation Ecology

Bill Gould,
Research Ecologist

I have been working on four projects in 2001. The studies focus on analyses of ecosystem properties such as vegetation composition, biodiversity, forest structure and biomass allocation in relation to climatic gradients, soil characteristics, topographic position, and forest age. The projects range in scale from plot-level descriptions of species composition and forest structure to mapping vegetation of the circumpolar Arctic. The study sites are in Puerto Rico, Idaho, Washington, Minnesota, Alaska, Canada, and the Circumpolar region.

The projects include:

The Puerto Rico Gap Analysis Project (PRGAP)

This project is the state-level representative of the National Gap Analysis Program sponsored by the Biological Resources Division of the United States Geological Survey. We are conducting landcover, vegetation, and vertebrate diversity mapping as well as analyses of patterns of land stewardship and conservation management in Puerto Rico. PRGAP will improve our understanding of biodiversity patterns and help in assessing the effectiveness of our conservation management strategies for Puerto Rico.

Landscape fragmentation and forest fuel accumulation: Effects of fragment size, age, and climate

This project is supported by the Joint Fire Science Program and involves remote sensing and field measures and analyses of fuel load characteristics in fragmented forests along gradients of climate, fragment size, and forest age in tropical, temperate, and boreal ecosystems. This project will help in our understanding of the ecological consequences of forest fragmentation and allow us to compare fragmentation effects along a large climatic gradient, particularly in terms of wildland fuel accumulation. Our experimental design involves sampling along transects from nonforested areas, across fragment edges, and into forested interiors. The primary goal is to determine whether fuel loads differ between forest edges and fragment interiors. Along each transect, we measured downed woody debris, canopy characteristics, and herbaceous cover. We tallied live and standing dead trees recording species, diameter at breast height, height, and crown dimensions. We also measured litter and organic matter layer depths, and collected subsamples of litter and organic layers to determine variation in the amount of combustible soil organic matter. We are conducting a multiyear decomposition experiment in a subset of these transects. The goal is to determine patterns of decomposition in coarse woody debris along gradients of location (outside, edge, or interior), climate, forest age, and fragment size.

Biocomplexity in biogeochemical cycles of Arctic frost-boil ecosystems

This project is supported by the National Science Foundation Biocomplexity in the Environment program. We are investigating a type of patterned ground (frost-boils) formed by the development of subsurface ice lenses in permafrost regions. Frost boils are common landscape features characterized by circular barren areas about 1 meter across surrounded by vegetated interboil areas. The biocomplexity research occurs at 11 sites including 6 in Alaska, and 5 in Canada. The research will increase our ability to predict ecosystem responses to climate change. My activities involve integrating undergraduate field education with the research component of the study and investigating biodiversity patterns associated with these ecosystems. A key feature of the field course is investigating variation in soil and vegetation characteristics along toposequence and climatic gradients.

Climate, substrate, and vegetation: distribution and causes of moist nonacidic tundra

This project is supported by the National Science Foundation and is an integral part of the Arctic Transitions in Land, Atmosphere, and Sea Program (ATLAS). My involvement includes the development of a Circumpolar Arctic Vegetation Map (CAVM) using remote sensing data, previous studies of vegetation, ancillary data, and field reconnaissance. The CAVM will provide a basis for circumpolar extrapolation of ecosystem processes.

Annual Letter Report

D. Jean Lodge,
Research Mycologist

Biosystematics of Tropical Fungi

Four papers were published or accepted for publication that describe 14 new species or varieties of higher fungi plus one new reported species for the Caribbean. Of these, 11 species were basidiomycete and 3 were ascomycete fungi. A new species of *Antrodia* that causes brown rot of pine logs was described from the Dominican Republic, as well as three new species of beneficial ectomycorrhizal symbionts of pine in the genus *Amanita*. One publication includes seven new species and varieties of *Hygrocybe* primarily from Puerto Rico. It is the second part of a monograph on the Hygrophoraceae resulting from a post doc fellowship for a mycologist, Sharon A. Cantrell, which was funded by the National Science Foundation (NSF) grant for “Basidiomycetes of the Greater Antilles” together with a Forest Service-funded National Research Council Fellowship.

The “Basidiomycetes of the Greater Antilles” grant to the State University of New York at Cortland ended in March 2001, and a final report was provided. In addition, a book chapter on biogeography of macrobasidiomycete fungi in the Greater Antilles was completed that summarizes the results of the grant and presents information on the distribution patterns of basidiomycete fungi found in the Greater Antilles and distributions of closely related taxa in the context of geologic and paleobotanic history. An additional summary of the results of this project was also published, and another is in press.

A new 3-year grant proposal was funded for $400,000 by the NSF beginning August 1, 2001. The grant will provide for continued biosystematics research on basidiomycete fungi in pine forests of the Dominican Republic and new comparative research in pine and other forest types in Belize.

The Role of Wood Decay Fungi in Soil Organic Matter Accumulation and Forest Nutrient Dynamics

Two workshops were held for synthesizing cross-site Long Term Ecological Research (LTER) data on maintanance of soil organic matter through decomposition. The workshops titled “Effects of Decomposing Wood on Soil” held in Corvallis, Oregon, specifically explored the role of decomposing coarse woody debris on soil.

Data in the literature suggested that the quantity and quality of carbon that enters the soil organic matter pool from decomposing wood may differ significantly between white- and brown-rot fungi. Differences in abundance of white- versus brown-rot fungi might affect the long-term stability of soil carbon, but long-term cross-site research is needed. Data on the effects of decomposing wood on soil organic matter are poorly known in the tropics, but decomposing woody debris from Hurricane Hugo was hypothesized to have stimulated microbial growth that tied up soil nitrogen, making it unavailable to tree roots and slowing canopy recovery (Lodge et al. 1994, Zimmerman et al. 1995).

In our preliminary analyses, we found that soil carbon per gram of soil in the upper 10 cm was significantly higher under 9.5-year-old logs felled by Hurricane Hugo than 0.5 m away, but only suggestively higher under 0.5-year-old Hurricane Georges logs. Soil nitrogen was significantly higher under 9.5-year-old logs (Hugo) and 0.5-year-old Georges logs versus 0.5 m away. Soil microbial biomass was significantly higher under versus 0.5 m away from decomposing logs in April 1999, but the reverse was true in September 2000. Fine root length was significantly lower under versus 0.5 m away from decomposing logs in April 1999 ($P < 0.001$), but the reverse was true in September 2000. The inverse relationship of fine root length with microbial biomass is consistent with the hypothesis that fungi and other microbes may outcompete roots for nutrients in high-carbon microsites under decomposing logs, but other explanations are possible.

One research proposal and one draft manuscript have resulted so far from these workshops. Research on the effects of decomposing wood on soil carbon, nitrogen, soil microbial biomass, and fine root proliferation was presented orally at the Oregon workshop as well as the Mycological Society of America meetings in 2001, and as a poster at the LTER all scientists meeting in August 2000.

English Equivalents

When you know:	Multiply by:	To get:
Grams (g)	0.0352	Ounces
Centimeters (cm)	.394	Inches
Meters (m)	3.28	Feet

Additional Accomplishments

Publications from 2001:

Biosystematics of tropical fungi:

Journal Publications (4)

Huhndorf, S.A.; Fernández, F.A.; Lodge, D.J. 1999. Neotropical ascomycetes 9. *Jobellisia* species from Puerto Rico and elsewhere. Sydowia. 51: 183-196. (3 new species, 2 from Puerto Rico; listed as "in press" in last year's report).

Cantrell, S.A.; Lodge, D.J. 2001. Hygrophoraceae (Agaricales) of the Greater Antilles, subgenus *Pseudohygrocybe* section *Firmae*. Mycological Research. 103: 215-224. (7 new species and 1 new report)

Lodge, D.J.; Ryvarden, L.; Perdomo, O. 2001. Studies in Neotropical polypores 11. *Antrodia aurantia*, a new species from the Dominican Republic, Greater Antilles. Mycotaxon. 80: 261-266. (1 new species and key to spp.)

Miller, O.K., Jr.; Lodge, D.J. [In press]. New species of *Amanita* from the Dominican Republic, Greater Antilles. Mycotaxon. (3 new species)

Literature reviews of fungal biosystematics in the Neotropics and project summaries for Basidiomycetes of the Greater Antilles (3).

Cantrell, S.A.; Lodge, D.J.; Baroni, T.J. 2001. Basidiomycetes of the Greater Antilles project. The Mycologist. 15: 107-112.

Lodge, D.J.; Baroni, T.J.; Cantrell, S.A. [In press]. Basidiomycetes of the Greater Antilles project. In: Watling, R.; Robinson, C.; Frankland, J.C., eds. British Mycological Society: tropical mycology symposium. Egham, UK: CABI.

Lodge, D.J.; Baroni, T.J.; Miller, O.K., Jr.; Halling, R.; Ryvarden, L. [In press]. Biogeography of Basidiomycete fungi in the Greater Antilles. In: Zanoni, T., ed. Biogeography of plants in the Greater Antilles. New York Botanical Gardens.

Methods for estimating species diversity (1):

Lodge, D.J. 2001. Diversidad mundial y regional de hongos. In: Hernández, H.M.; García-Aldrete, A.; Alvarez, F.; Ulloa, M., eds. Enfoques contemporáneos para el estudio de la biodiversity. Ciudad Universitaria, Mexico: Ediciones Científicas Universitarias, Serie Texto Científico Universitario, Instituto de Biología, Universidad Nacional Autónoma de México: 291-304.

Reviews in peer-reviewed journals (1):

Lodge, D.J. 2001. Implications for nitrogen additions from air pollutants on litter decay fungi and ecosystem processes, Mycological Research News, Mycological Research. 105: 770-771.

Lodge, D.J. 2001. North American boletes: a color guide to the fleshy pored mushrooms. In: Bessette, A.E.; Roody, W.C.; Bessette, A.R. 2000.

Presentations at meetings (names in italics are the presenters)

Oral presentations:

***Lodge, D.J.*; Clum; N.C.; Winter, D.** Effects of decomposing logs on soil carbon, nitrogen and soil microbial biomass at the Luquillo-LTER site. Effects of decomposing wood on soil workshop. Corvallis, OR.

***Brokaw, N.*; Haines, B.L.; Lodge, D.J.; Walker, L.R.; Thompson, J. 2001.** Dominance by shrubs and medium-sized trees in early regrowth after a hurricane in tropical forest. Association for Tropical Biology. Bangalore, India.

***Lodge, D.J.*; Baroni, T.J.; Cantrell, S.A.** Basidiomycetes of the Greater Antilles. Caribbean biodiversity: an international conference integrating science and policy. Punta Cana, Dominican Republic.

Lodge, D.J.; Winter, D.; Clum, N.C. 2001. Competition by soil microbes with roots under decomposing logs. Mycological Society of America, annual meetings, Salt Lake City, UT.

Poster presentations:

***Lodge, D.J.*; Xiaoming, Z.; Clum, N.C.** 2000. Effect of decomposing coarse woody debris on soil carbon, nutrients, and microbial biomass. [Poster]. In: LTER all scientist meeting; 2000 August; Snowbird, UT.

Lebrón, L.; *Lodge, D.J.*; Laureano, S.; Bayman, P. 2001. Where is the gate to the party? [Poster]. In: Mycological Society of America, annual meetings; 2001 August; Salt Lake City, UT.

***Lebrón, L.*; Lodge, D.J. 2001.** Correlation of VA colonization with development of *Cercospora coffeicola* infection in leaves of coffee seedlings. [Poster]. In: 3rd international congress on mycorrhizae; 2001 July; Adelaide, Australia.

Miscellaneous

Grant proposal funded:
"Basidiomycetes of Neotropical Pine Forests: Connections Between a Possible Refugium in Belize and Endemic Pine Forests in the Dominican Republic." National Science Foundation, Biotic Surveys & Inventories, 1 August 2001 to 31 July 2004: $400,000.

Awards

- Fellow of the Mycological Society of America, August 2001
- Elected Councilor in Ecology/Pathology, Mycological Society of America, August 2000-2003

Symposia and workshops organized/chaired

- Co-organized and chaired the following cross-site LTER workshop: Effects of decomposing wood on soil, 5-9 April 2001, Corvallis, Oregon.
- Organized with the MSA Fungal Biodiversity Committee and Chaired: Fungal Biodiversity Symposium. Mycological Society of America, Annual Meetings, Salt Lake City, UT, 25-29 August, 2001.

Presentations and workshops

Presented on the ecological roles of fungi, Introductory Mycology Class, University of El Turabo, Puerto Rico, 24 April 2001.

Reports

- Final report for the Basidiomycetes of the Greater Antilles grant, NSF.
- International Travel report: evaluation of pine bark beetle damage in Belize

Editor

- Subject Editor for Biotropica 1999-2001.
- Served as an Associate Editor for Mycological Research since Jan. 2001

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Lodge, D.J.; McDowell, W.H.; McSwiney, C.P. 1994. The importance of nutrient pulses in tropical forests. Tree. 9(10): 384-387.

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Ecological Research

Ariel E. Lugo,
Ecologist

In this section, I summarize some of the research results and analyses that I published this fiscal year with several colleagues on montane cloud cover of the Caribbean, urban forestry, biodiversity management, and comparison of forests in Puerto Rico with continental forests.

Montane Cloud Forests of the Caribbean

Silver et al. (2001) summarized existing information on montane cloud forests in the Caribbean region and made recommendations for future research. They discussed the geographic distribution; the physical environment, structure, and productivity; the diversity of plants and animals; the effects of disturbance and land use; biotic interactions; human geography; and problems for conservation. Montane forests in the Caribbean cover a small geographical area, which, added to their slow growth rate and increasing human pressures, makes them extremely vulnerable to human disturbance. Silver et al. (2001) focused the discussion on sites in Puerto Rico and Jamaica, where there has been a long history of ecological research, and discussed to a lesser extent forests in Guadeloupe, Cuba, Martinique, and the Dominican Republic.

Urban Forestry

Urban forestry is rapidly gaining public and scientific attention. Yet, although much has been written about temperate urban forests in continental areas, there is little information on insular and tropical urban forests. Urban forest conservation, as well as research activity, can benefit from clear definitions of the types and characteristics of urban forests (Lugo 2002). In the process of developing a definition of the urban forest, it is necessary to consider the area occupied by the forest, age of trees, tree species diversity, types of species that compose the forest, tree density, and the shape of the forest stands. These considerations help characterize the urban forest and show how it adjusts to the urban environment. A definition of the urban forest has to also consider geographical, as well as ecological, space concepts. “Urban forest” is a geographical concept that restricts the urban forest concept to a particular location. Yet many types of forest stands occur within the urban environment. These respond to diverse ecological conditions and can be grouped according to ecological composition and functioning. A classification was developed that categorizes urban forest stands into four types: (1) natural matrix, (2) natural corridors, (3) green oasis, and (4) artificial corridors (fig. 1).

Management of Biodiversity

There is general agreement among ecologists on how human activity is causing global change. Deforestation, atmospheric ozone depletion, increased concentration of greenhouse gases, erosion, desertification, and species extinctions are a few examples of the global effects of human activity. These trends are expected to continue into an era known as the Homogeocene, when human effects on Earth will be even more obvious than today. There is disagreement among ecologists on

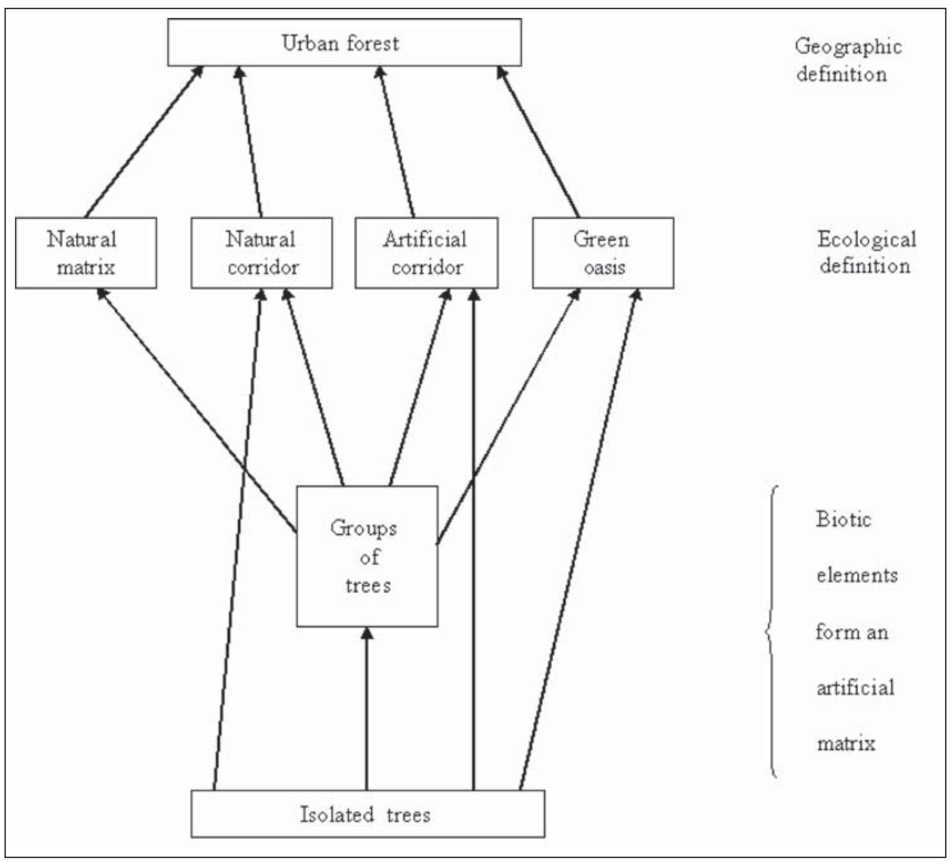

Figure 1—Diagram of the hierarchical nature of the urban forest.

how to approach the conservation of the world's biodiversity both today and in the Homogeocene. Ecosystem management with a focus on function is advocated as the approach for the conservation of biodiversity. Such an approach values all species, including alien species, and uses multiple seeding, ecosystem self-design and resilience, and land rehabilitation as the guiding principles of conservation. I developed these ideas in Lugo (2001).

Comparison of Island and Continental Forests

The Dinghushan Biosphere Reserve, in subtropical continental China, was compared with the Luquillo Experimental Forest Biosphere Reserve, in subtropical insular Puerto Rico (Ding et al. 2001). Long-term research histories in both locations allow for pairing of data sets on climate (figs. 2 through 4), topography, geology, soils, disturbance regimes, flora, fauna, microbial communities, and ecosystem structural and functional parameters for the dominant plant association in each location. The two forest associations that were compared are the tabonuco forest in Puerto Rico and the monsoon evergreen broadleaf forest in China. Physiognomy, biomass, leaf area index, primary productivity, and water and nitrogen cycling parameters for these forest types are compared. Both forest types are subject to similar human and natural disturbances, with the difference being that the continental forest had a longer history of human intervention and was subjected to lower temperatures than the insular forest.

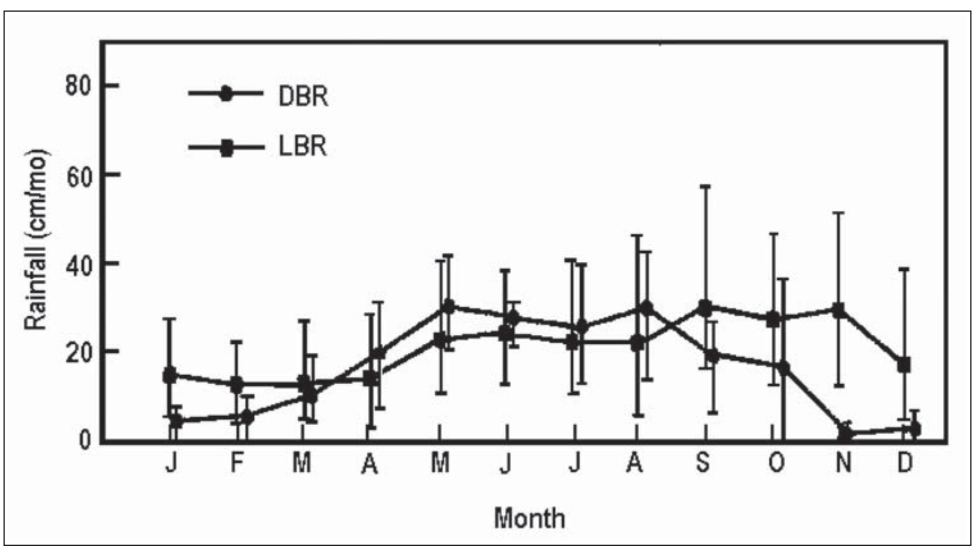

Figure 2—Comparison of annual pattern of maximum, minimum, and mean monthly rainfall at Dinghushan (DBR) and Luquillo (LBR) Biosphere Reserves. Data are averages for 6 years for the DBR (Huang Zhang-fan and Fan Zeng-guang 1982) and 12 years for the LBR (Brown et al. 1983).

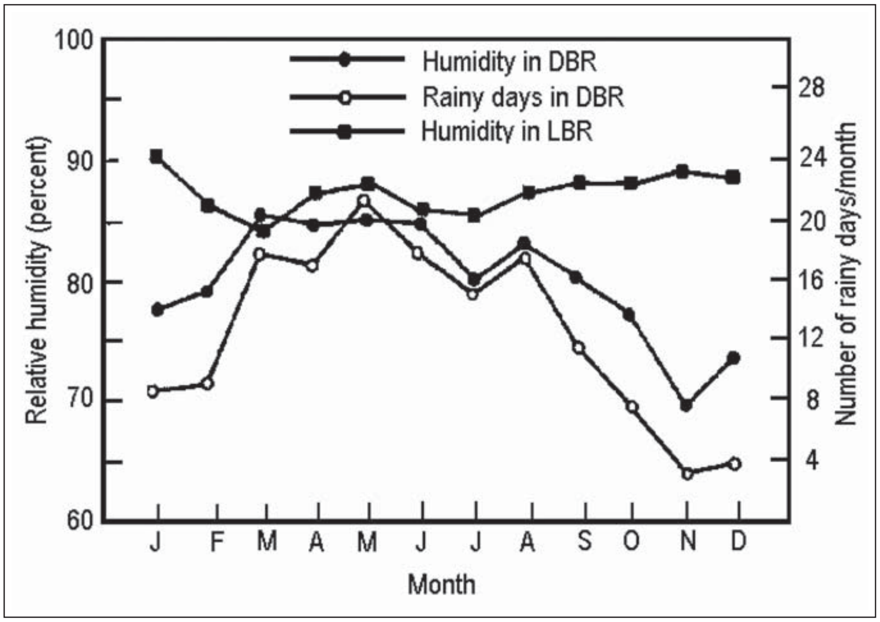

Figure 3—Comparison of relative humidity at Dinghushan (DBR) and Luquillo (LBR) Biosphere Reserves. Data are from (Huang Zhang-fan et al. (1982) and Briscoe (1966).

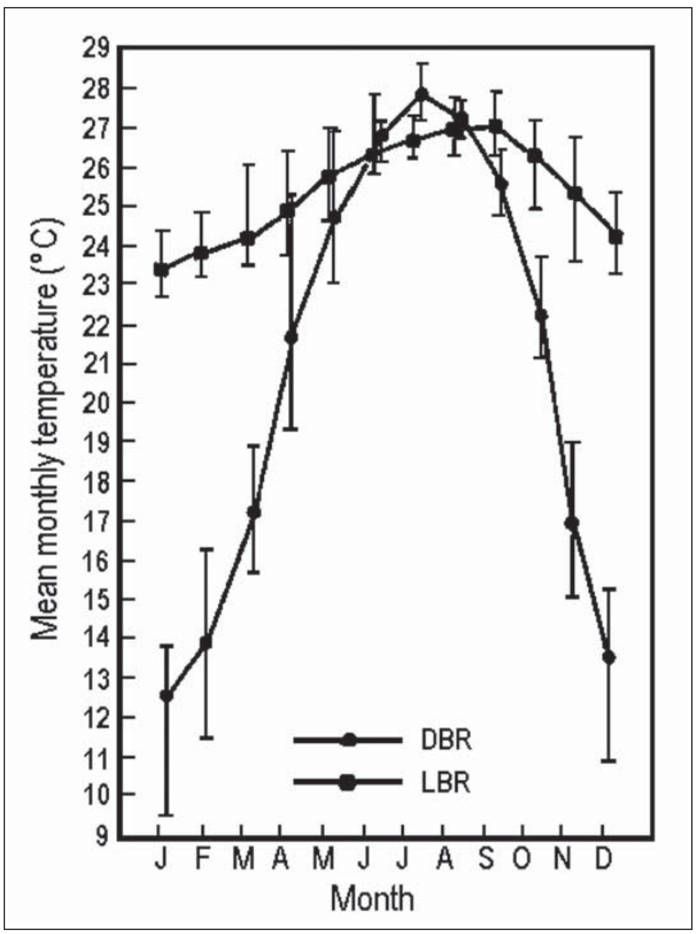

Figure 4—Annual patterns of maximum, minimum, and mean monthly temperatures at Dinghushan (DBR) and Luquillo (LBR) Biosphere Reserves. Data are averages for 6 years for the DBR (Huang Zhang-fan and Fan Zeng-guang 1982) and 12 years for the LBR (Brown et al. 1983).

In the tabulation below, human uses of the forests were also compared and we found many similarities in spite of cultural differences. However, the forests shared similar community structure as measured by species dominance curves (fig. 5). Comparisons such as these are a first step toward understanding the factors that regulate forest structure, function, and species composition, and they are useful for elucidating the degree to which insularity or continentality can be used as a factor for explaining the structure and functions of ecosystems.

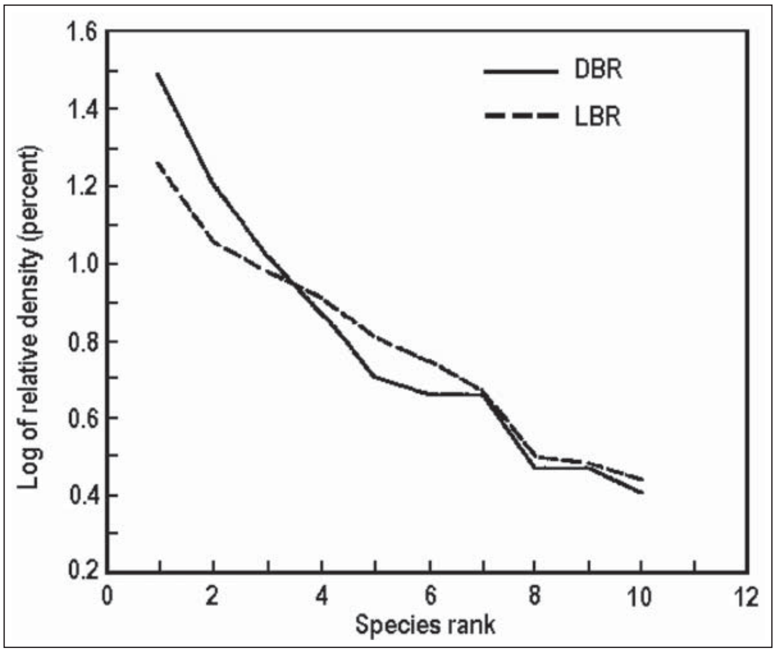

Figure 5—Species dominance curves for trees ≥10 cm in diameter at breast height at Dinghushan (DBR) and Luquillo (LBR) Biosphere Reserves.

Uses and products with economic value of the Dinghushan and Luquillo Biosphere Reserves

Dinghushan Biosphere Reserve

- Water. There are two major streams; 1200 ha of farmland with a production of 6096 (Mg) per year of rice irrigated at a cost of 1.2 million RMB[1]; streams can supply clear drinking water to 7,000 people worth 50,000 RMB per year.
- Litter. In the buffer and transition areas, about 1463 (Mg) per year of litter and shrubs, worth 576,000 RMB, were removed by farmers as fuel.
- Religions. There are two temples; 200,000 people per year worship in them.
- Tourism. There are 600,000 tourists per year.
- Panorama. This reserve can be used as an example for research on panorama ecology in the subtropics.
- Education. Six hundred students and 500 visitors have been trained per year.
- Medical recuperation. There is a sanatorium in the buffer zone; 500 to 600 people per year come to recuperate from diseases.
- Source of germ plasm. About 250 kg per year of seeds and seedlings of several species of various plants spread to the area surrounding the reserve.
- Research. There are 7 universities or schools and 8 institutes that have been working on hydrology, meteorology, geography, geology, plant taxonomy, plant physiology, plant ecology, plant ecophysiology, entomology, zoology, microbiology, and soil science since China's revolution; scientists from more than 10 countries or districts, such as Australia, France, Germany, Hong Kong, Italy, and the United States, have been studying and examining this reserve; writers and artists also work there.

Luquillo Biosphere Reserve

- Water. There are dozens of water intakes, including several small reservoirs; use of the water is free, but permits are required from the U.S. Department of Agriculture, Forest Service; the authors estimate that well over 200,000 people receive their water from this reserve; after Hurricane Hugo, the Caribbean National Forest was the only available clean water source for people who lived around its periphery.
- Spiritual and national symbol. Known locally as El Yunque, the Luquillo Biosphere Reserve is a national symbol with spiritual roots in the Taino Indian culture, which gave El Yunque Mountain religious properties as the home of the god Yuquiyu; today, the mountain generates commercial value when used for advertisements, and the country as a whole is very protective of its current management and future use.

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[1] RMB = chinese currency.

- Tourism. The authors estimate close to a million people visit each year; about half are from outside Puerto Rico. A tourist can easily spend $75 on a day tour to El Yunque.
- Panorama. This reserve has a superb panorama that serves as an attraction to tourists and others seeking recreation.
- Education. Training activities range from hundreds of students from public schools who take field trips in the area, to college students to international forestry and ecology professionals who visit for training and research.
- Research. This reserve has been the subject of research activity for over 100 years; today, some 100 scientists have active research programs in the forest, which is the subject of the U.S. National Science Foundation Long-Term Ecological Research Program, and the U.S. Geological Survey’s Water, Energy and Biogeochemical Budgets Program; it also houses research staffs of the Forest Service and U.S. Fish and Wildlife Service and the University of Puerto Rico’s Terrestrial Ecology Division.
- Special-use permits. Also classified as the Caribbean National Forest, it supports many special uses with economic returns; a few examples are transmission and communications towers, which influence most of the commercial communication traffic in Puerto Rico; manual fishing in streams for freshwater shrimp; minor extraction of wood, mosses, and other forest products; and the use of East Peak for national defense training.

English Equivalents

When you know:	Multiply by:	To get:
Centimeters (cm)	0.394	Inches
Kilograms (kg)	2.205	Pounds
Hectares (ha)	2.47	Acres
Megagrams (Mg)	1.102	Tons

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Ding, M.M.; Brown, S.; Lugo, A.E. 2001. A continental subtropical forest in China compared with an insular subtropical forest in the Caribbean. Gen. Tech. Rep. IITF-17. Río Piedras, PR: U.S. Department of Agriculture, Forest Service, International Institute of Tropical Forestry. 46 p.

Huang, Zhang-fan; Fan, Zeng-guang. 1982. The climate of Ding Hu Shan. Tropical and Subtropical Forest Ecosystem. 1: 11-23.

Lugo, A.E. 2001. El manejo de la biodiversidad en el siglo XXI. Interciencia. 26(10): 484-490.

Lugo, A.E. 2002. What is an urban forest? In: Zimmerman, T.W., ed. Proceedings of the 5th annual Caribbean urban forestry conference. St. Croix, Virgin Islands: University of the Virgin Islands, Cooperative Extension Service: 12-15.

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Long-Term Wildlife Research

Wayne J. Arendt,
Research Ornithologist

Caribbean-Wide

Biometrics of Birds Throughout the Greater Caribbean Basin

For more than 40 years, our colleagues and others have been requesting morphometrics data about Caribbean birds. We will soon have a readily accessible, comprehensive, and easy-to-use source encompassing a diverse assemblage of the region's avian taxa. *Biometrics of Birds Throughout the Greater Caribbean Basin* (Arendt et al. 2004) will fill a very palpable void and, more importantly, will continue to expand in scope, content, and relevance. This depository of avian morphometrics is the result of (1) more than 40 years of data collection, (2) more than 20 years of preparation, and (3) expert knowledge of four ornithologists who have worked throughout the region. It includes a representative sample of the Caribbean's avifauna, i.e., meristics of birds representing more than 50 islands, islets, and cays and constituting 17 orders, 46 families, 21 subfamilies, 138 genera, almost 300 species, and more than 20,000 birds, with as many as 9 external morphological characters measured per individual.

Montserrat

Rapid Decline of the Montserrat Oriole

Prior to 1995, the Montserrat Oriole, *Icterus oberi,* was confined to about 30 km^2 of hill forest on the Lesser Antillean island of Montserrat but was not listed as globally threatened (Arendt and Arendt 1984). Since then, the eruption of the Soufriere Hills volcano has destroyed more than half of the species' range (Arendt et al. 1999). Intensive monitoring throughout the late 1990s and early 2000s has indicated that the species population has also declined dramatically within the remaining intact forest and is now critically threatened (Hilton et al. 2003). Monitoring and analysis indicate a decline of 8 to 52 percent per year (fig. 1), and a remaining global population of approximately 100 to 400 pairs.

Despite intensive monitoring and the use of several analytical methods, it has proved surprisingly difficult to estimate the magnitude of the oriole's decrease, or to control for potential artifacts in the census methods such as silent period vs. tape-playback period, investigator bias, weather conditions, and physiognomy of the vegetation, among others. Causes behind the population decline in the intact

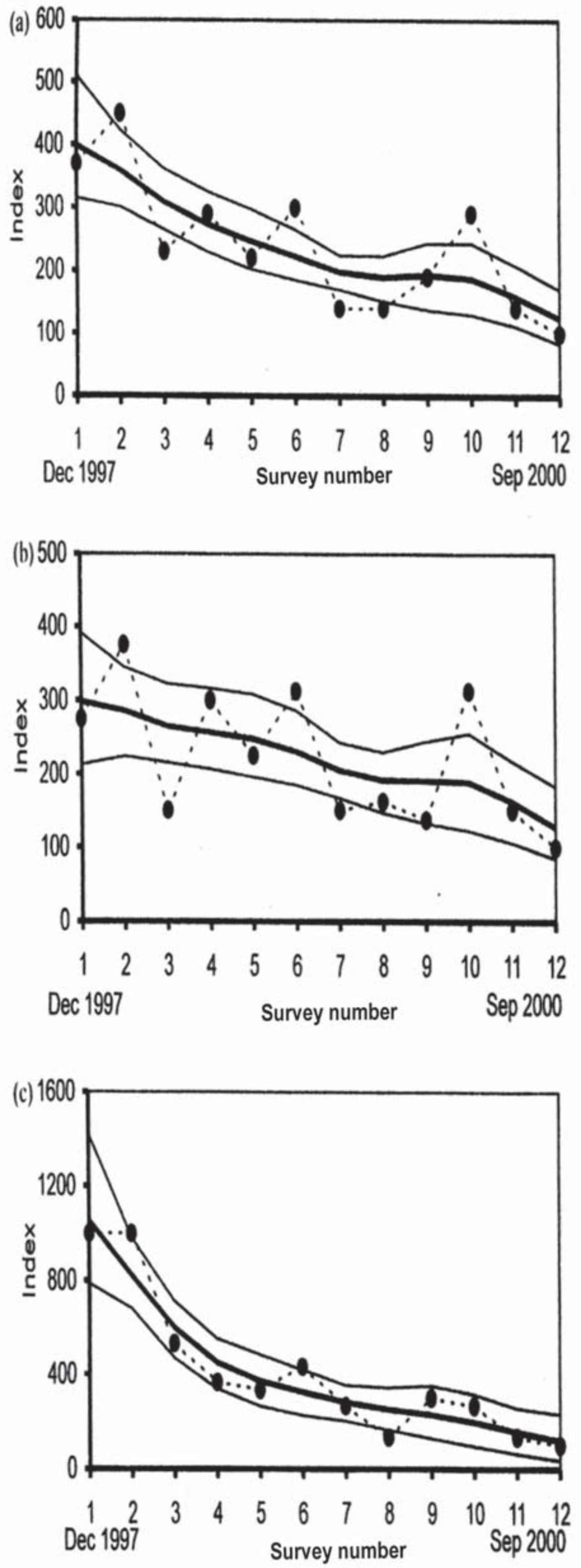

Figure 1—Apparent decline in the Montserrat oriole population in the Center Hills, 1997-2000. (from Hilton et al. 2003) Dashed lines: Underhill indices for the 12 quarterly censuses. Values are scaled to equal 100 in September 2000. Thick solid line: General Additive Model (GAM) values for the Underhill indices. Thin solid lines: 95 percent confidence intervals, calculated by bootstrapping, for GAM values. (a) total oriole counts (silent period and tape-playback period combined); (b) oriole counts from the 10-minute silent period only; (c) oriole counts from tape-playback period only.

forest are unclear, although two hypotheses appear plausible: a decrease in arthropod food supply as a result of volcanic ash fall, and an increase in nest predation as a result of increases in populations of opportunistic omnivores.

Status, Distribution, and Reproductive Ecology of the Montserrat Oriole Prior to Recent Volcanic Eruptions (Arendt and Arendt, n.d.)

On Montserrat, many species of native and endemic fauna are in danger of being added to the ever-growing list of global extinctions owing to recently increasing, cataclysmic climatic and geological disasters, skyrocketing land development, and the current substantial loss of arable lands in the southern two-thirds of the island. Because of the uncertainty of the island's future in light of these events, and owing to a paucity of life-history information on the island's fauna in general, we document the status and various ecological aspects of the island's only endemic bird, the Montserrat Oriole prior to major habitat disturbances and widespread habitat loss caused by Hurricane Hugo in 1989 and the more recent volcanic eruptions beginning in the 1990s, which, to date, have destroyed 60 to 76 percent of the species' prime habitat. Our information serves as a baseline with which to compare pre- and postdisturbance populations and many of their respective distributional and reproductive parameters in the ongoing efforts to study, preserve, and manage the species (see, for example, Arendt et al. 1999; Gibbons et al. 1998; Hilton et al. 2003; Owen 2000; Williams 2000a, 2000b).

Management of the Montserrat Oriole's Captive and Wild Populations

Prompt action by the Montserrat Alliance, a consortium of conservation bodies led by the Royal Society for the Protection of Birds (RSPB) in the United Kingdom, resulted in the implementation of successful conservation and research programs such as the Durrell Wildlife Conservation Trust's outstanding oriole propagation at the Jersey Zoo and the RSPB's ongoing field research program that monitors population size and fluctuation, reproductive success, and other factors affecting the oriole's numbers. However, despite all of these measures, upon evaluation of the ongoing population censuses, which continue to show a drastic downward trend, coupled with an erratic breeding success, general consensus is that the future of the Montserrat Oriole is precarious, and the species should be classified as critically threatened (Hilton et al. 2003).

Management and research programs should not only be continued but also broadened to include the real and potential effects of such factors as genetic bottlenecks, and all of the ramifications and consequences of genome reduction and inbreeding.

Puerto Rico

Effects of Hurricane Georges on the Composition, Abundance, and Survival of Winter Residents in the Guánica Forest of Southwestern Puerto Rico

We have been monitoring bird populations in the Guánica Forest of southwestern Puerto Rico for more than 30 years, with a single net line since 1973 and with multiple net lines (maximum of nine) since 1989. As a result, we can examine both short- and long-term effects on winter resident birds of the extensive damage done to the forest by Hurricane Georges in September of 1998 (Faaborg et al. 2002). Such a long-term perspective may be necessary because capture rates vary greatly, ranging from 6 to 14 species and from 75 to 170 individuals captured annually (figs. 2 and 3).

Hurricane Georges did not affect number of species or individuals captured, with record high numbers in 2001 and near record lows in 2002. Numbers of Northern Parula (*Parula americana*) and prairie warbler (*Dendroica discolor*) have been high posthurricane, and both rose-breasted grosbeak (*Pheucticus ludovicianus*) and prothonotary warbler (*Protonotaria* citrea) became briefly abundant at that time (fig. 4). Survival rate modeling using program MARK supported a decrease in survival rates for ovenbirds (*Seiurus aurocapilla*) (47 percent vs. 20 percent) in relation to the hurricane, but survival rates of worm-eating warbler (*Helmitheros vermivorus*) (56 percent) and the black-and-white warbler (*Mniotilta varia*) (49 percent) were not similarly affected (tables 1 and 2). In general, the effects of hurricane damage at this site appear minor and transitory and may be much less severe than the effects of widespread drought on the breeding grounds, which we feel is the cause when very low populations are observed (as in 2002).

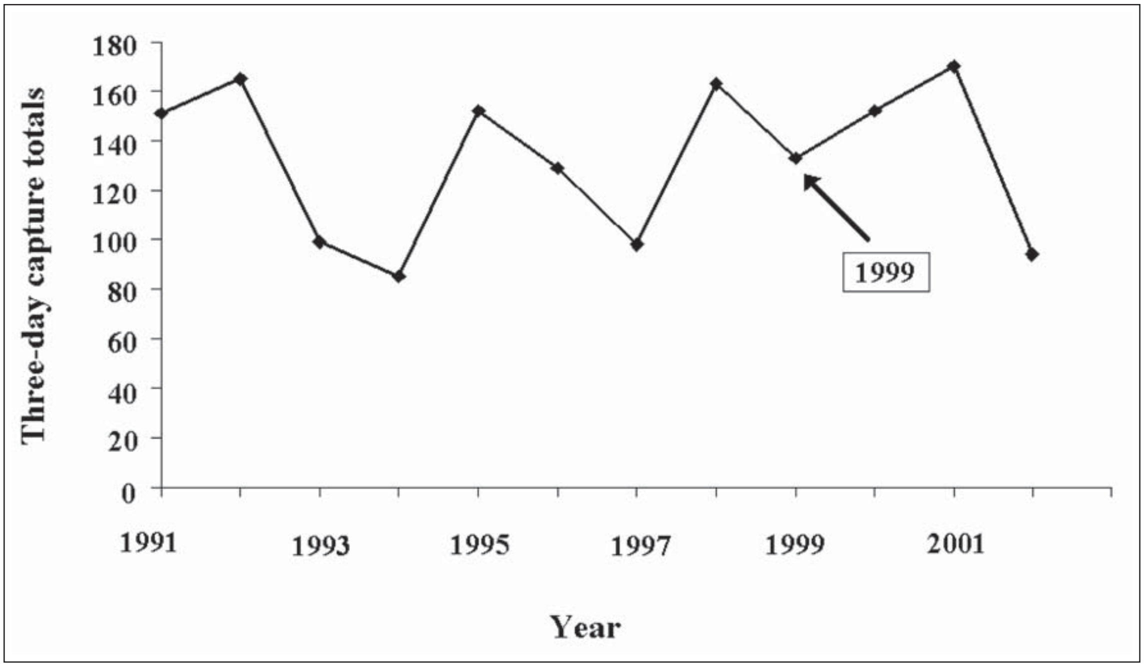

Figure 2—Twelve-year migrant capture totals.

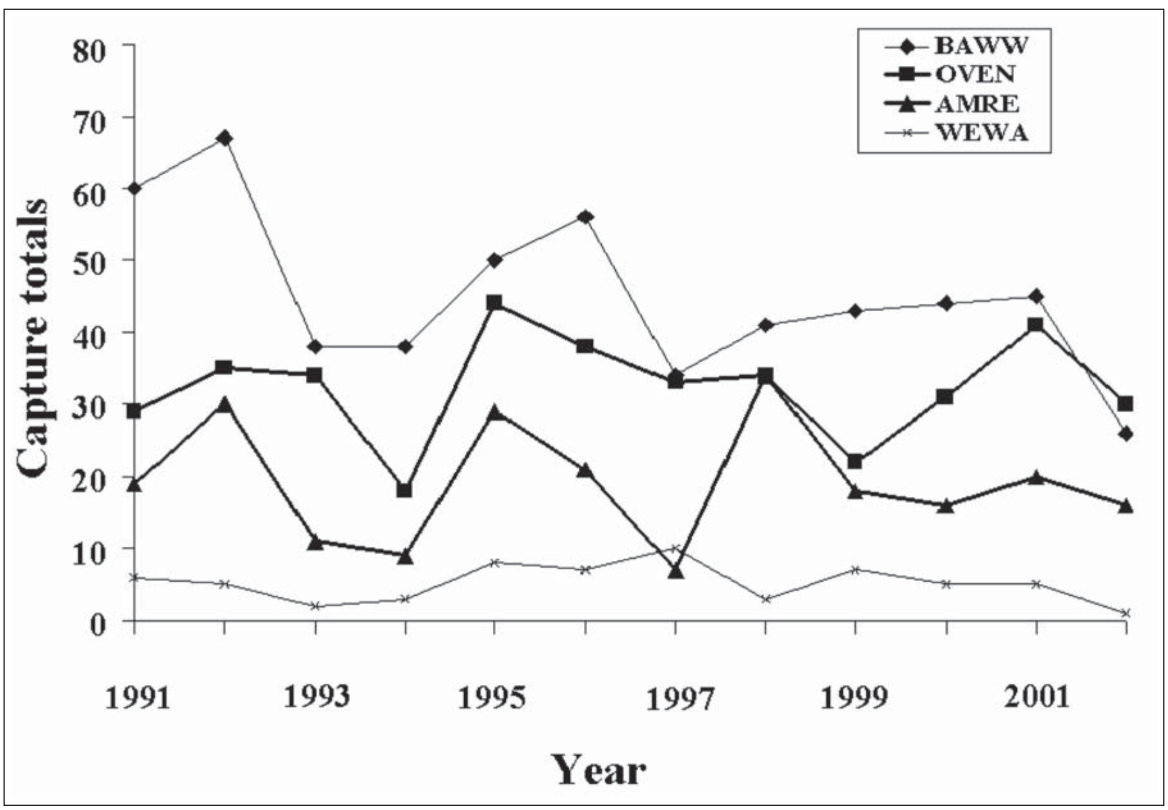

Figure 3—Annual capture totals for black-and-white warbler (BAWW), ovenbird (OVEN), American redstart (AMRE), and worm-eating warbler (WEWA).

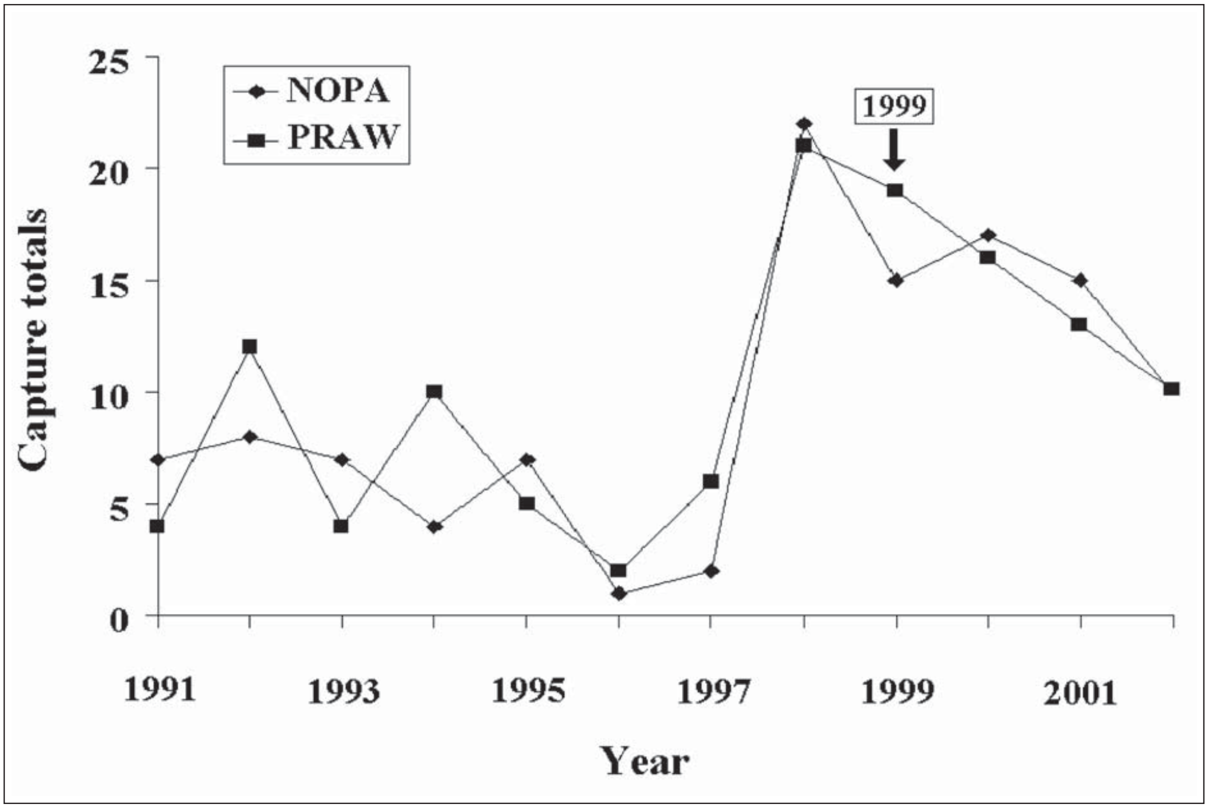

Figure 4—Annual capture totals for Northern parula (NOPA) and prairie warbler (PRAW).

Table 1—Model selection results: the top three models for each species with corresponding Akaike's Information Criteria values adjusted for small sample sizes (AIC_c), Delta AIC_c values, AIC_c weights, and the number of parameters in the model (np)

Species	Model	AIC^c	Delta AIC_c	AIC weight	np
Ovenbird	Φ_{Hurr} P	586.95	0.00	0.64	3
	Φ P	589.89	2.94	.15	2
	Φ $P_{(t)}$	590.34	3.40	.12	14
Black and white warbler	Φ P	851.72	.00	.62	2
	Φ_{Hurr} P	852.69	.97	.38	3
	Φ $P_{(t)}$	862.05	10.33	.004	14
Worm-eating warbler	Φ P	115.81	.00	.75	2
	Φ_{Hurr} P	118.01	2.20	.25	3
	Φ $P_{(t)}$	131.37	15.56	.003	14

$\Phi_{(Hurr)}$ P = hurricane effect on survival, constant capture probability.
Φ P = constant survival and capture probability.
Φ $P_{(t)}$ = constant survival and time-dependent capture probability.

Table 2—Survival estimates and capture probabilities, with standard errors (SE) and 95 percent confidence intervals (CI) from the best model for each species

Species	Survival estimate	95% CI	Capture probability
	Percent (SE)		*Percent (SE)*
Ovenbird	Nonhurricane 0.48 (0.04)	0.40 – 0.55	0.37 (0.05)
	Hurricane 0.20 (.09)	0.08 – 0.43	
Black-and-white warbler	0.49 (0.03)	0.43 – 0.56	0.29 (.04)
Worm-eating warbler	0.56 (0.08)	0.40 – 0.71	0.35 (.10)

English Equivalents

When you know:	Multiply by:	To get
Square kilometers (km^2)	0.386	Square miles

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Wildlife Research

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

Endangered Species Management

Limiting Access of Predatory Snakes to Parrot Nest Cavities

Nest predation is often the leading cause of mortality for many tropical birds and is a particular threat to endangered bird species, such as the Puerto Rican parrot (*Amazona vittata*).

Currently, predation of nestlings by snakes is not a serious threat to the Puerto Rican parrot in the palo colorado forest of the Luquillo Experimental Forest (LEF). However, nestling predation by snakes (i.e., Puerto Rican boa, *Epicrates inornatus*) is likely to be a major mortality factor in the karst or limestone region south of Arecibo, the proposed site for future releases of captive-reared Puerto Rican parrots. Unlike in the palo colorado forest of the LEF, Puerto Rican boas are common in the karst region and are expected to pose a potential threat to parrot nest success as they are in the karst region of Jamaica (Koenig 2001). Indeed, Koenig attributed nest mortality in the Jamaican karst region to the yellow boa (*Epicrates subflavus*), a species closely related to the Puerto Rican boa.

Thus, vital to preserving the Puerto Rican parrot in this region is an understanding of the traits of parrot nest cavity trees that make them attractive to boas. Identification of such traits trees might permit active management of Puerto Rican parrot nest trees to discourage use by predatory boas. We obtained such information through radio-telemetry studies of Puerto Rican boas in the LEF as well as statistical analyses done in collaboration with Bernard Parresol of the Southern Forest Experiment Station. The studies were designed to identify the traits of broadleaf trees used by boas.

Our studies revealed that vine coverage was one of the most distinctive traits of broadleaf trees used by boas in the LEF (fig. 1). Vines provide access to trees from the ground as well as from other trees or shrubs and provide dense cover for foraging and resting.

Size of tree was another important factor in boa use. Vines are more abundant on large trees in the LEF, which partially explains the presence of boas in trees of larger diameter at breast height (d.b.h.) relative to randomly sampled trees (fig. 1).

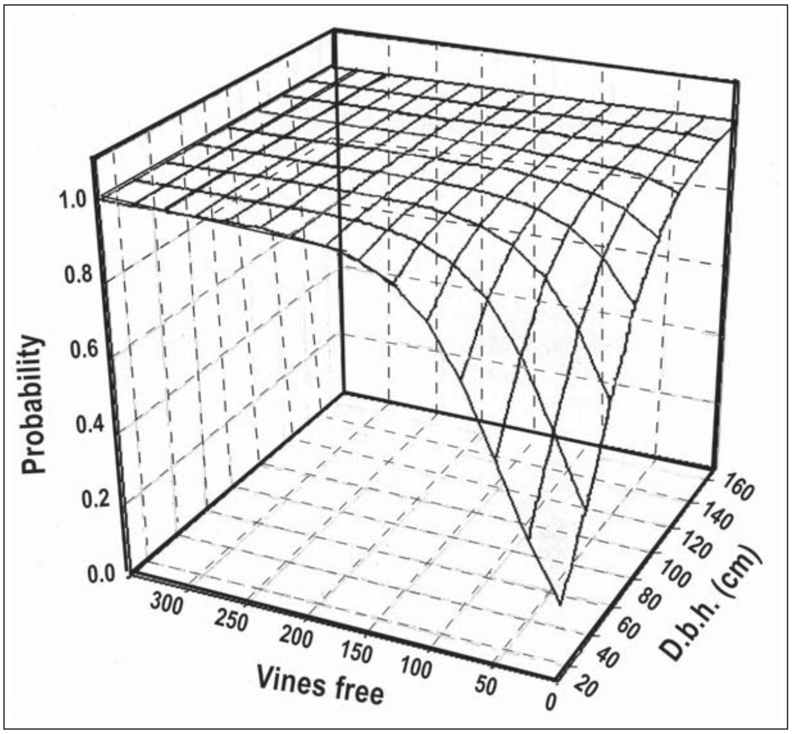

Figure 1—Logistic regression response surface showing the probability of a tree being attractive for habitation by a Puerto Rican boa in the Luquillo Experimental Forest based on tree diameter at breast height (d.b.h.) and quantity of vines attached to the tree.

Big trees also are likely to provide the larger diameter perches used by heavier snakes. In addition, tree cavities, which may be used by boas for resting or locating prey, are likely to be more common and larger in trees of large than small d.b.h. Finally, large trees may have larger crowns, increasing the likelihood of contacting the crowns of neighboring trees and providing the vegetation continuity required for arboreal snake movements in the canopy (e.g., Tolson 1988).

Given the importance of vegetative continuity and vine cover for movement of arboreal snakes, it is expected that prey species would avoid sites with such traits if possible. Indeed, Snow (1976) has suggested that some species of tropical forest birds nest in isolated trees without vines or canopy continuity to avoid nest predators, including snakes. The risk of nesting in sites accessible to snakes is evident in Jamaica where parrots nesting in cavities in trees covered with vines or with high canopy connectivity were more likely to have chick losses than those nesting in cavity trees lacking these traits (Koenig 1999, 2001). The evidence, independent of vegetation traits, strongly suggested to Koenig that nestling losses were due to predation by the yellow boa, which is further supported by our boa habitat data.

Managers concerned with potential nest predation by snakes might consider clipping vines from nest cavity trees to limit access by climbing snakes. In addition, if nest tree crowns are interconnected with crowns of surrounding trees, it is also important to trim canopy branches to eliminate canopy interconnectedness, further limiting access by arboreal snakes. A metal barrier wrapped around the tree trunk would further limit snake access to cavity nests. Although such management activities are labor intensive, they may be necessary for management of critically endangered species such as the Puerto Rican parrot.

Kirtland's Warbler and Associated Species in the Bahamas

The Kirtland's warbler (*Dendroica kirtlandii*) is one of North America's most endangered bird species. Intensive recovery effort has been focused on its Michigan breeding grounds. Little is known, however, about the species on its wintering areas where it is confined to the Bahamas Archipelago. Recent studies indicate that wintering ground events can affect migrant populations, and the absence of wintering ground information and conservation efforts could compromise Kirtland's warbler breeding ground conservation efforts. Thus more information is needed on the Kirtland's warbler and its winter habitat. Also needed is to build the capacity of island residents to undertake conservation management activities in the Bahamas.

To accomplish these objectives, we initiated a research and training project in collaboration with Eric Carey of the Department of Agriculture of the Bahamas and David Ewert of The Nature Conservancy. Field work for the project was initiated in forests on the island of Andros where avian surveys were conducted in a variety of habitats from January to April 2002 with participation of two students from the college of the Bahamas. In addition, six Kirtland's warblers were captured and banded at a site on the island of Eleuthera. The Kirtland's warbler site, discovered by the ornithology group of the Bahamas National Trust, is extraordinary given that at least eight individual Kirtland's warblers were observed at the site in early April along 230 m of rural road. Planned field work for fiscal year 2003 was to focus on this Eleuthera site to characterize the behavior and ecology of the Kirtland's warbler and associated species at the site and to determine the traits that make this site attractive to the bird.

Ongoing Research

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

We continued our studies on birds and bats in the Tapajós National Forest, near Santarém in the Brazilian Amazon. Although field work was completed in July 2001, data analysis was conducted in collaboration with Michael Willig of Texas Tech University and researchers from the Emilio Goeldi Museum in Belém, Brazil. Analyses of data from this work was expected to be completed in fiscal year 2003.

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

This study is based on surgically implanted radio transmitters, which enable us to use radio telemetry to locate and follow snakes in the LEF. Field work was completed in June 2001, and we have completed most of the analyses and expect to complete the work in fiscal year 2003.

Phenology of Common Tree and Vine Species That Produce Fruits Consumed by the Puerto Rican Parrot

We have now completed the sixth year of this fruiting phenology study designed to monitor fruit production of some of the common tree and vine species with fruits and seeds important to the endangered Puerto Rican parrot. The study involves monthly sampling along two trails in the palo colorado forest of the LEF and has characterized phenologies for 2 years prior to Hurricane Georges and 4 years of recovery in the storm's aftermath. This work is not only valuable for characterizing variation in the food supply for the parrot but will allow us to better understand the timing of breeding in the parrot and pearly-eyed thrasher (*Margarops fuscatus*), both species with breeding seasons that may be synchronized with fruiting phenologies. This study continued into fiscal year 2003.

Puerto Rican Parrot Recovery, 1973-2000

I am currently working with participants from the Puerto Rican Parrot workshop, which IITF sponsored in 1995, and others involved in the recovery effort to summarize and evaluate the parrot's population biology and the overall success of the recovery effort. The goal of the project is to identify critical research needs and areas in which increased management intervention could increase population growth rate. A summary of this work was presented at the North American Ornithological Congress in New Orleans (Wunderle 2001). Revisions of the manuscript are expected to be completed in fiscal year 2003.

Publications

Two papers (Mercado et al. 2002, Wunderle 2001) and three abstracts of presentations at professional meetings were published (Carey et al. 2002, Wunderle 2002, Wunderle et al. 2002) in fiscal year 2001. A brief note was published (Mercado et al. 2002) summarizing avian mobbing of the Puerto Rican boa. Mobbing, defined as an intense collective behavior in which birds scold or even attack a predator, is known from a variety of bird species. However, mobbing of snakes has never been documented in the West Indies, and we summarized our observations of different bird species mobbing Puerto Rican boas in the LEF. One book review was completed summarizing and evaluating a massive and very useful bibliography of West Indian birds by James Wiley (Wunderle 2001). Research results were summarized in three presentations at meetings.

English Equivalents

When you know:	Multiply by:	To get:
Centimeters (cm)	0.394	Inches
Meters (m)	3.28	Feet

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Major Research and International Cooperation Activities

Peter L. Weaver,
International Cooperation

International Cooperation

The International Cooperation group was involved in several activities in Nicaragua and Panama. In Nicaragua, a report on the Mombacho Volcano Natural Reserve was completed and reviewed by local participants. In Panama, we completed and internally reviewed a slide program and also a detailed report on the San Lorenzo Protected Area (SLPA). The SLPA, one of the many reverted properties in the old Canal Zone, is located at the northwest entrance to the Panama Canal. In addition, the status of big-leaf mahogany in Panama was investigated by using the same format as for previous reports done in Belize and Nicaragua. The above information is being reviewed for publication and will be described in more detail in subsequent annual letters.

Past Work in the Dominican Republic

West Indian Walnut

The West Indian walnut (nogal), *Juglans jamaicensis* (Juglandaceae), a species native to the Dominican Republic and Puerto Rico, is currently endangered because of habitat destruction (Veloz and Salazar 2001). Twenty-seven walnut populations totaling 1,394 individuals were located in the Cordillera Central, the Sierra de Neiba, and the Cordillera Septentrional of the Dominican Republic at elevations between 330 and 1510 m. Walnut grows in association with 500 other species in 317 genera and 100 families. Of these, 10 percent are endemic, 73 percent native, and 12 percent introduced, and the remaining 5 percent identified only to genus. Eight biological life forms including epiphytes (29 species) and parasites (2 species) were represented among the associated species. Walnut flowers and fruits between February and July, and grows in soils ranging from acid to slightly alkaline. Soil phosphorus and potassium were recorded at low levels, whereas calcium ranged from moderate to relatively high. Locally, the walnut is used mainly in carpentry and home construction. The seeds are edible and the leaves are used in home medicines. Despite the walnut's endangered status, its regenerative capacity is sufficiently high so that it should recover once human activities are mitigated.

Natural Regeneration in Dry Community Forests

Two types of dry forest in two conditions (cut, uncut) in the Dominican Republic were compared with regard to species composition and natural regeneration (Vidal and Casado 2001). Cutting of both forests reduced the number of species present after 5 years. Thirty-nine tree species in both forests were evaluated by their natural regeneration in cut and uncut conditions.

Research

Thinning Stimulates Ingrowth

A 50 percent basal area reduction in Puerto Rico's colorado forest had little immediate impact on diameter at breast height growth for most residual stems (Weaver 2001). A slight positive response was evident for several species after 5 to 30 years. Instead, thinning served as a major stimulus for massive ingrowth of two common colorado forest species important to the Puerto Rican parrot (*Amazona vittata*): palo colorado (*Cyrilla racemiflora*), the major parrot nesting tree, and cupeíllo (*Clusia clusioides*), a major source of food. Canopy opening appeared beneficial for the survival and regeneration of laurel sabino (*Magnolia splendens*), an uncommon tree used by the parrot for nesting and food. Other species that showed substantial increases in stem numbers were palo de hueso (*Haenianthus salicifolius*) and camasey (*Miconia tetrandra*).

Posthurricane Affects on Vegetation

Ridges in the lower montane rain forests of Puerto Rico and the Lesser Antilles from St. Kitts to Grenada are dominated by tabonuco (*Dacryodes excelsa*), a long-lived tree adapted to recurrent hurricanes (Weaver 2002a). The oldest tabonuco trees in Puerto Rico appear to survive 500 to 600 years in forests that periodically (perhaps every 50 to 60 years) lose nearly one-fifth of their biomass. Posthurricane recovery, characterized by greater rates of stem ingrowth and mortality, showed an immediate and abundant regeneration of yagrumo hembra (*Cecropia schreberiana*) along with numerous small- to medium-size species in forest openings. Stem density, species numbers, and the rate of biomass accumulation are at a maximum 15 years after a hurricane; about 50 years later, most of the secondary species associated with past forest disturbance have disappeared and the rate of biomass accumulation becomes asymptotic.

Reforesting Urban Areas With Transplants

Major transplanting of mature urban trees is a new practice in Puerto Rico that was started in response to pressures by environmental groups to protect urban trees (Weaver 2002b). From early April to late September 1997, 129 trees (of the 150 trees that were moved to new sites) were monitored after being transplanted in Bayamon (Weaver 2002b). The four species transplanted were bottlebrush (*Callistemon citrinus*), cayeput (*Melaleuca quinquinervia*), big-leaf mahogany (*Swietenia macrophylla*), and white cedar (*Tabebuia heterophylla*).

The trees ranged from 4.5 to 50.0 cm in diameter at breast height and from 1.7 to 12.5 m in height. An estimated 1880 m^3 of soil was removed during transplanting, 20 percent as wrapped root balls, 31 percent as soil excavated to extract trees, and 49 percent as the planting sites. Root ball ratios ranged from 4.5 to 15.4, with 80 percent of the ratios less than 10. Root ball ratios equal the ratio of the diameter of the root ball including roots and soil to the diameter of the transplanted trees as measured near ground level.

Two months after transplanting, 4 bottlebrush and 12 cayeput were dead, and after 4 months, 8 and 13, respectively were dead. After 4 months, an additional 25 percent of the bottlebrush and 36 percent of the cayeput had lost foliage. All the mahoganies and white cedars survived the first 3 months. About 75 percent of the trees suffered trunk damage during transplanting.

Many factors may influence tree transplanting in Puerto Rico, among them the tree species selected, transplanting techniques, and climatic and economic considerations. Planting seedlings and saplings of select fast-growth tree species is a viable alternative to transplanting mature urban trees and may constitute a more efficient means to reforest many urban areas. Puerto Rico's arborists need to formulate a comprehensive urban forest strategy in conjunction with the public.

Post-Georges Effects on Vegetation

The Puerto Rican Conservation Trust, among other objectives, encourages terrestrial and aquatic research at the Cabezas de San Juan Nature Reserve located in the Fajardo suburbs of northeastern Puerto Rico (Weaver and Coll Rivera 2002). The reserve's sampling of semievergreen secondary woodland after hurricane Georges showed that 21 percent of the trees were uprooted, snapped, leaning, or dead. Permanent plots in the abandoned coconut plantations revealed a 9 percent loss of stems owing to the storm. Leucaena (*Leucaena leucocephala*), numerically dominant in the coconut plantation, averaged more than 1 cm/year growth in diameter.

Restoration plantings of six native species in the coconut plantation showed that after 1.8 years, only oxhorn bucida (*Bucida buceras*) and white fiddlewood (*Vitex divaricata*) survived and grew satisfactorily.

Growth Performance of Trees Planted in Cabo Rojo and Laguna Cartagena Wildlife Refuges

Since the early 1980s, about 9,000 trees representing nearly 80 species have been planted in the Cabo Rojo and Laguna Cartagena National Wildlife refuges in southwestern Puerto Rico. During 2002, their growth and short-term survival were evaluated and the results presented at the 11th Caribbean forester's conference held in St. Thomas, U.S. Virgin Islands. This work will be discussed in more detail in future annual letters.

English Equivalents

When you know:	Multiply by:	To get:
Centimeters (cm)	0.394	Inches
Meters (m)	3.28	Feet
Cubic meters (m^3)	35.3	Cubic feet

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State and Private Forestry Accomplishments

Terry L. Hueth,
State and Private Forestry Program Manager

State and Private Forestry in the U.S. Virgin Islands

The cooperative programs are administered and implemented through a partnership between the government of the U.S. Virgin Islands (USVI), the USDA Forest Service, and many other private and government entities (table 1). These programs promote the health and productivity of the USVI's forest lands and rural economies. Emphasis focuses on timber and other forest products, wildlife, water resources, rural economies, and conservation practices. The goal is to maintain and improve the health of urban and rural forests and related economies. These programs:

- Reduce costs through the use of partnerships.
- Increase values through sustained productivity of forests.
- Facilitate synergism between traditional and nontraditional partners.
- Are voluntary and nonregulatory in their delivery.

Key issues that the territory addressed in implementing the 2002 budget were (table 1):

- Urbanization and sprawl into natural areas.
- Ecological restoration of natural and built-up areas.
- Soil protection and watershed management.
- Sustainable urban forestry program.
- Creation of jobs and income using natural-resource-based opportunities.

The USVI has 22 270 ha of privately owned forest land and 57 ha of experimental forest. Of the estimated 570 individuals owning forest lands, most have parcels smaller than 8 ha. Almost all of these landowners report that agriculture and aesthetics are primary reasons for owning forest land. The territory's 120,000 people include 44 communities with populations over 100 residents; 41 percent of these have initiated some level of community forestry program (table 2).

Urban and Community Forestry

The International Institute of Tropical Forestry State and Private Forestry staff and International Programs staff, with support from the University of the Virgin Islands, cooperated in a joint effort June 9-14, 2001, in St. Thomas, USVI, for the 7th annual Caribbean urban forestry conference and the 11th Caribbean foresters meeting. The theme was "The Future of Trees in the Caribbean: Biology,

Table 1—Investment in the U.S. Virgin Islands Cooperative Programs

Program	Federal funds	Match funds	Total funds
		Dollars	
State Fire Assistance	17,000	0	17,000[a]
Cooperative Lands Forest Health	20,000	0	20,000[a]
Economic Action Programs	30,000	0	30,000[a]
Forest Legacy	40,000	13,420	53,420
Forest Stewardship	55,000		55,000
National Fire Plan State Fire Assistance	40,000	0	40,000[a]
National Fire Plan Volunteer Fire Assistance	33,000	0	33,000[a]
Urban and Community Forestry	50,000	50,000	100,000[a]
Volunteer Fire Assistance	10,000	0	10,000[a]
Totals	295,000	63,420	358,420

[a] Funds were used to reimburse wildland fire suppression costs stateside.

Table 2—Forest facts and accomplishments for the U.S. Virgin Islands

Selected facts	Total	Selected results	Total
Population	120 000	Stewardship plans prepared (current year)	1
Hectares of forest land	22 265	Hectares under stewardship plans (current year)	220
Hectares of nonindustrial private forest land	22 265	Hectares under stewardship plans (all years)	465
Hectares of private land under state fire protection	35 995	Rural hectares planted	68
Number of rural fire departments	0	Technical assists to private landowners	186
Number of cities and towns	44	Cities and urban areas assisted	25
Forest-based employment	None	Firefighters trained	120
Forest-based earnings	Minimal	Hectares surveyed for forest health	5 597

Planning, and Management.” There were more than 168 participants representing 16 countries, 2 territories, and 6 states.

We provided ongoing technical assistance in support of the International Society of Arboriculture for Puerto Rico and Virgin Islands in a cooperative agreement. The International Institute of Tropical Forestry (IITF) staff participated as trainers in the International Society of Arboriculture workshops; conducted International Society of Arboriculture exams, and participated as proctors and assistants to the proctors during the exam.

We provided assistance in the recruitment of a new Forest Stewardship Program and Urban and Community Program coordinator.

State and Private Forestry served as an active member, provided guidance, and participated on projects with the Virgin Islands Urban and Community Forestry Council.

Cooperative Fire Protection

The entire territory can be classified as an urban-wildland interface. In this island environment, there are very few rivers, no lakes, limited humanmade ponds, and a limited number of fire hydrants. Variable trade winds, fuel buildup associated with dry tropical forests, narrow and steep roads, and difficult building entrances all combine to create a wildfire challenge. During the year, the Fire Service contracted for basic wildland fire training for all of its employees. The emphasis in the program is to have trained firefighters with proper safety equipment and clothing. Consideration is also being given to the potential for developing dry hydrant installations in freshwater ponds for additional water sources. National Fire Program funds are available in both State Fire Assistance and Volunteer Fire Assistance to improve firefighting capability, along with implementing stronger fire prevention and Fire Wise home protection programs. This year the funds were not available for projects, owing to the repayment of the wildland fire suppression costs stateside.

Forest Stewardship

Matching natural resource professionals with farmers and other landowners is expanding the vision for forest stewardship opportunities in the territory. Recognizing the importance of protecting habitat for wildlife, soil for water quality, and aesthetics for tourism and economic development changes the way people view the opportunities and their responsibility for a healthier island. The accomplishments in the program are growing slowly as landowners begin to realize the need to actively manage their lands for the overall health of the island environment. The stewardship position for the Virgin Islands has been vacant and was filled in July 2001. One plan was completed on St. Croix.

Forest Health Protection

We are working with the University of the Virgin Islands Coop Extension Service to compile and disseminate information about identification and management of pests of importance to the local forest systems and to provide technical assistance and training in Integral Pest Management to pest managers, state and private land managers, and Department of Agriculture personnel.

Economic Action

The Virgin Islands Resource Conservation and Development Council is an active partner in delivering the economic action program. Supporting the existing resources for helping established and newly developed business, the council strives to increase job and income opportunities that utilize the islands' natural resources. We have provided assistance with the council to award a grant to the Virgin Islands Department of Justice, Bureau of Corrections called the Golden Grove Wood Craft Project. The goal of the project is to teach inmates at the Golden Grove Adult Correctional Facility how to create products made of wood and to hand paint these products. The intent is to teach skills that will allow the inmates to become self-sufficient upon release through the practice of creating and selling woodcrafts.

Natural Resource Conservation Education

The Virgin Islands ReLeaf Program addresses the territory's need for new tree planting, tree care information, and education. The Virgin Islands ReLeaf provides trees for schools, benefiting 2,000 students annually. The Trees for Schools program teaches students the benefits of trees and their proper care, thus encouraging greater pride in the schools and the islands. The Forest Service Conservation Education Program is being refocused to coordinate through the St. Croix Environmental Association Conservation Education Coordinator for the distribution of materials and curriculum guides, such as the *Natural Inquirer*.

Forest Legacy

The goal of the Forest Legacy Program is to effectively protect and conserve environmentally important forest areas that are threatened by conversion to nonforest uses. This is a voluntary land conservation program between the USDA Forest Service, state, or territorial governments, land trusts and private landowners. The program uses fee acquisition or conservation easements to protect lands in a conservation trust. The USVI Department of Agriculture has prepared, through The Nature Conservancy, an Assessment of Need. This study was sent to the USDA for approval and funding as a startup project for fiscal year 2003. This study, and resulting document, evaluates the present forest resources, the values of these forests, and the threat to this resource from conversion to other land uses.

State and Private Forestry in Puerto Rico

The cooperative programs are administered and implemented through a partnership between the government of Puerto Rico, the USDA Forest Service, and many other private and government entities. These programs promote the health and productivity of Puerto Rico's forest lands and rural economies. Emphasis focuses on timber and other forest products, wildlife, water resources, rural economies, and conservation practices. The goal is to maintain and improve the health of urban and rural forests and related economies (table 3).

These programs:

- Reduce costs through the use of partnerships.
- Increase values through sustained productivity of forests.
- Are voluntary and nonregulatory in their delivery.

Key issues that Puerto Rico addressed in implementing the 2001 program were:

- Rapid urbanization and sprawl into natural areas.
- Water quality, including stormwater runoff, and restoration of natural areas.
- Soil protection and watershed management.
- Sustainable urban forestry programs at the local level.
- Creation of jobs and income utilizing natural-resource-based opportunities.

Table 3—Investment in Puerto Rico's cooperative programs

Program	Federal funds	Match funds	Total funds
		Dollars	
State Fire Assistance	20,000[a]	0	20,000
Cooperative Lands Forest Health	74,000[a]	0	74,000
Economic Action Programs	30,000[a]	0	30,000
Forest Legacy	600,000	150,000	750,000
Forest Stewardship	205,000[a]	0	205,000
National Fire Plan State Fire Assistance	42,000[a]	0	42,000
Urban and Community Forestry	150,000[a]	0	150,000
National Fire Plan Volunteer Fire Assistance	31,000[a]	0	31,000
Total	1,152,000	151,000	1,303,000

[a] Funds were not granted but were used to reimburse wildland fire suppression costs stateside.

Puerto Rico has 505 400 ha of forest land, of which 43 600 ha is in public ownership, including the 11 300 ha in the Caribbean National Forests. Of the 19,951 individuals owning forest lands, most have parcels smaller than 8 ha. Almost all of these landowners report that conservation, aesthetic enjoyment, and recreation are primary reasons for owning forest land. The Commonwealth's 3.8 million people include 78 municipalities. All have initiated some level of community forestry program (table 4).

Urban and Community Forestry

State and Private Forestry coordinated a CITYgreen™ workshop for the representatives of the Municipalities of Cataño, San Juan, Toa Baja, Carolina, Guaynabo, Bayamón, Loiza and Trujillo Alto, University of Puerto Rico-Mayaguez Campus Extension Service in Mayagüez, Department of Natural and Environmental Resources for the use and management of the CITYgreen™ software as a tool for land use planning and implementation of environmentally safe development practices in areas adequate for development and protecting the surrounding communities and inhabitants.

State and Private Forestry provided technical assistance and workshops for the improvement of urban forest management and establishment for community members and groups:

- Autoridad de Edificios Públicos
- Municipio de Trujillo Alto
- Municipio de Caguas
- University of Puerto Rico, Cayey Campus
- Centennial Wireless, Telemarketing Division Employees
- University of Puerto Rico, Río Piedras Botanical Garden
- International Society of Arboriculture

Products available in Spanish (technical sessions power point presentations):

- Árboles y Construcción (Trees and Construction Sites)
- Biología de los Árboles (Tree Biology)
- Instalación de Cables y Abrasaderas (Cabling and Bracing)
- Técnicas para Subir Árboles y Seguridad (Climbing Techniques and Safety)
- Conceptos Básicos de Poda (Pruning)
- Ecosistemas (Ecosystems)
- Necesidades Nutricionales de los Árboles (Tree Fertilization)
- Hormonas de las Plantas (Tree Hormones)
- Humedales (Wetlands)
- Identificacion de Árboles (Tree ID)

Table 4—Forest facts and 2001 accomplishments for Puerto Rico

Selected facts	Total	Selected results	Total
Population	3.8 million	Stewardship plans prepared (current year)	18
Population density, people per square mile	1,000	Hectares under stewardship plans (current year)	915
Percentage of protected lands	5	Stewardship plans prepared (all years)	87
Hectares of forest land	505 004	Hectares under stewardship plans (all years)	1694
Hectares of nonindustrial private forest land (NIPF)	461 405	Technical assists to private landowners	455
Number of NIPF landowners	19,951	Firefighters trained	160
Number of tracts in forest legacy program	9	Number of forest legacy tracts acquired (current year)	0
Total hectares of forest legacy tracts	578	Hectares of forest legacy tracts acquired (current year)	0
Hectares of federal land under state fire protection	0	Hectares surveyed for forest health	4047
Hectares of private land under state fire protection	889 662	Forest health assistance visits	43
Number of rural fire departments	0	Cities and towns assisted	78
Number of municipalities	78	Economic activity grants to rural areas	0

- Reciclaje (Recycling)
- Relación Suelo y Agua (Soil and Water Relation)
- Siembra y Establecimiento de Árboles (Tree Planting and Establishment)
- Sistemas de Riego (Irrigation Systems)
- Árboles y Huracanes (Trees and Hurricanes)
- Conservación de los Recursos Naturales (Natural Resources Conservation)

State and Private Forestry also provided technical assistance to the seventy-eight (78) municipalities of Puerto Rico. The participation of community leaders and the collaboration with state, federal, and municipal government has increased. Sembrando por Puerto Rico (now called Proyecto Puertorriqueño de Reforestación) a tree planting and educational program sponsored by the Department of Natural and Environmental Resources and encouraged the participation of the community members and the support of conservation initiatives developed not only by the government but also by the community members.

To improve nursery management, IITF, State and Private Forestry Program in cooperation with the University of Puerto Rico-Mayagüez Campus Extension Service are distributing among private nursery landowners a Spanish version of *The Container Tree Nursery Manual* and *Fertilizing and Water Management*. We also completed the Urban Forest Effects Inventory for the San Juan basin.

Cooperative Fire Protection

State and Private Forestry provided funding for basic wildland fire training to support the local and national suppression efforts. Most of the funds were used to pay for the stateside suppression wildland fire costs.

Forest Stewardship

The program has continued to grow with an increase in the number of stewardship plans prepared for individual forest landowners. A total of 18 plans were prepared this year. By focusing on contiguous areas within critical watersheds, the program has made improvements in management with significant cumulative effects. To date, 87 plans totaling 1694 ha have been prepared. Numerous agreements have been made between federal and commonwealth agencies, and nonprofit organizations that have resulted in ongoing survey and mapping work, along with land protection through the Forest Legacy Program.

Forest Health Protection

During the year, technical assistance was provided to 43 individuals or nurseries, and 4046 ha were surveyed for forest health. The University of Puerto Rico-Mayaguez Cooperative Extension Service staff maintains the database listing pesticides available for the control of pests common to forests, shrubs, palms, urban trees, and ornamental woody plants.

Economic Action

There has been no economic action for this year owing to support for wildland fire suppression costs stateside.

Natural Resource Conservation Education

A new memorandum of understanding (MOU) was signed by the University of Puerto Rico, the Puerto Rico Department of Education, and IITF to facilitate continued cooperation in conservation education to support the Long-Term Ecological Research (LTER) being done by six high schools. Francisco Morales High School, Naranjito (two plots): The evaluation of a research area started with the identification of tree species and the collection of loose litter samples. The Land Use and Ownership Study was initiated by Juan Ponce de León High School and Florida Research Station, and the priorities have been developed. Luis Muñoz Rivera High School, Utuado is looking at the possibility of a second research area.

In Pablo Colón Berdecía High School, Barranquitas, the Land Use and Ownership Study was initiated. In Luz America Calderón High School, in the 4th school district of Carolina, the research area was visited to determine work progress and the impact on the area of the "Museo del Niño" construction. In University Gardens High School, Río Piedras, the research area was visited to determine project status.

Forest Legacy

The goal of the Forest Legacy Program is to effectively protect and conserve environmentally important forest areas that are threatened by conversion to nonforest uses. This is a voluntary land conservation program between the USDA Forest Service, Puerto Rico Department of Natural and Environmental Resources, land trusts, and private landowners. The program uses fee acquisition or conservation easements to protect these lands forever. Continuation of the MOU specifications signed between the Secretary of the Department of Natural and Environmental Resources and the Executive Director of the Citizens of the Karst (CDK) for continued cooperation in protection of the Karst Region through collaborative planning, land acquisition and management. The CDK identifies the properties suitable for acquisition based on the project goals and conservation initiatives, including use of geographical information systems, identified for the Karst Region.

A grant of $600,000 was awarded to the Puerto Rico Department of Natural and Environmental Resources for the fee acquisition of properties in the Karst Region, in cooperation with the Citizens of the Karst and the Trust for Public Land. Land appraisals were completed and the processes to purchase parcels have been initiated by the Trust and Citizens of the Karst. The acquired properties under the Forest Legacy Program now include 9 tracts totaling 579 ha.

English Equivalents

When you know:	Multiply by:	To get:
Hectares (ha)	2.47	Acres

International Cooperation Highlights

Kathleen McGinley,
International Cooperation Staff

During fiscal year 2002, International Cooperation (IC) staff managed joint projects and provided advice and technical assistance to environmental representatives and organizations throughout Latin America and the Caribbean. The IC staff also designed and coordinated short-term assignments in support of these projects, taking advantage of International Institute of Tropical Forestry (IITF) scientists and technicians, as well as identifying technical experts throughout the Forest Service, universities, and the private sector. Highlights of major activities are presented here.

Regional Work

International staff worked with counterparts in Latin America and the Caribbean on issues such as big-leaf mahogany; environmental education; and forest, watershed, and protected area management. Additionally, we responded to more than 40 requests for information on forest research and management from countries such as Brazil, Ecuador, Ireland, Madagascar, the Philippines, and elsewhere around the world. The IC staff carried out extensive work in the Dominican Republic, Panama, Nicaragua, Brazil, Guyana, Haiti, and Jamaica. Specific details follow.

Dominican Republic:

- Coordinated, managed, and subsequently completed a major component of the Hurricane George Reconstruction Program in the Dominican Republic. This interagency agreement between the U.S. Agency for International Development (USAID) and the USDA Forest Service was designed to provide technical assistance, equipment and materials for improved land management in the aftermath of Hurricane George. In fiscal year 2002, IITF continued to assist the Dominican government in forest land recuperation and collaborated with the State Subsecretariat of Forest Resources on forest land management, planning, and protection. Activities included a national urban forestry assessment and in-country training by Integrated Urban Forestry of Southern California for approximately 60 individuals. The IITF extended technical assistance in wildfire detection, suppression, and communication and helped develop a reforestation operations center for the upper watershed of the Artibonito River.
- Assisted in the development of the USAID/ Dominican Republic Environmental Strategy on Biodiversity and Tropical Forests.

- Contributed to the development of an international partnership for the conservation of Bicknell's thrush and other Neotropical migratory birds of the Dominican Republic. Partners include the USDA Forest Service, The Nature Conservancy, The Vermont Institute of Natural Science, and the Dominican nongovernmental organization Fundación Moscoso Puello.
- Assisted in research and documentation on:
  - Natural regeneration in dry community forests in the Dominican Republic.
  - The ecological aspects and habitat destruction of the endangered West Indian walnut (*Juglans jamaicensis*) in the Dominican Republic.

Panama:

International Cooperation activities were greatly facilitated in Panama by having an IC staff member resident there as the Natural Resources Manager for the USAID mission for most of the year. The manager was a Forest Service employee, and was supported through the Foreign Agricultural Service/International Cooperation and Development with an agreement with USAID.

- In collaboration with the nongovernment organization (NGO) Panamanian Center for Social Studies and Action (CEASPA), developed a comprehensive environmental education slide program and technical report on the historical, cultural, and natural resources of the San Lorenzo Protected Area. This 12 000 ha protected area is located at the northwest entrance to the Panama Canal and forms part of the Mesoamerican Corridor of protected areas that extend from the Yucatan Peninsula of Mexico to the Panama-Colombia border.
- Authored, designed, and printed visitor guide map for the San Lorenzo Protected Area.
- Provided advice and oversight for USAID contracts and grants in natural resource management and environmental education and communication with NGOs, such as the following:
  - GreenCOM environmental education and communication programs: Work with underserved rural communities and schools in the Panama Canal Watershed to improve the livelihoods of community members and lead to better land use practices.
  - CLARA, Central America water-monitoring coalition of NGOs: Works with underserved rural and urban schools in the Panama Canal Watershed teaching children techniques of water monitoring and the effects on communities and individuals from contaminated water.
  - The Peregrine Fund Cooperative Agreement: Developing an education program in rural schools in the Panama Canal Watershed concerning the long-term conservation of the harpy eagle (*Harpia harpyja*) and other birds of prey.

- The Nature Conservancy/Fundación Natura/Panama Environmental Trust Fund: Provides small grants to local communities and nonprofit groups for conservation programs in the Panama Canal Watershed. Also provides funding and technical assistance for reforestation, education, ecotourism, and pollution control activities to underserved communities.

- In collaboration with the Panama National Environmental Authority, German Technical Cooperation, and local NGOs, helped produce an environmental education manual and field laboratory kit.
- In coordination with RARE Center for Tropical Conservation and Panamanian NGOs, planned community-level nature guide training program. (Currently, RARE is in search of funding for implementation.)
- Researched and documented the occurrence of big-leaf mahogany (*Swietenia macrophylla* King) in Panama. This publication details the change in coverage of big-leaf mahogany from the mid-1600s through the present, as well as the changes in policy regarding its extraction in Panama.
- In collaboration with the Panamanian NGO Asociacion para el Fomento al Turismo (AFOTUR), assisted the Embera Drua community in community development and ecotourism. Activities included planning and construction of nature trails, production of promotional materials, and Web site design.
- Assisted in the development of interpretive materials and signage for the Metropolitan Nature Park in Panama. This 265-ha park, lying just outside Panama City, is noted as the only tropical forest park within a metropolitan area in Latin America. The signs and interpretive materials orient visitors and provide them with important information on the park's flora, fauna, and environmental functions.
- Developed a signage planning and design manual for the Metropolitan Nature Park, which serves as a model to be used by similar parks throughout Central America.

Nicaragua:

These activities were implemented in cooperation with USAID through an agreement similar to that in Panama, with IITF providing salary for IC staff and technical experts.

- Assisted in the development and realization of studies that encompass vegetation monitoring, local wildlife surveys and bird monitoring in the Mombacho Volcano Natural Reserve.
- In cooperation with the Nicaraguan NGO Fundación Cocibolca produced a report (in review) on the Mombacho Volcano Natural Reserve to be used for education and increased visibility.
- Assisted the Nicaraguan Environmental Authority with development of promotional and interpretative materials for seven national parks.

- In cooperation with the Nicaraguan Environmental Authority and local NGOs, assisted in the development of a tourism concept plan for the Juan Venado Natural Reserve. Field work was carried out by the USDA Forest Service Heritage Design Enterprise Team.

Brazil:

- Provided support for the Large-Scale Biosphere Atmosphere project. Specifically, supported research on the relationship between tropical forests and the global atmosphere, the effects of single-tree selective logging in the Brazilian Amazon and remote sensing of logging damage. This research is carried out by an IITF research scientist.
- Provided support for research on the life history and management of natural and planted big-leaf mahogany in the Brazilian Amazon.

Guyana:

- Participated in the regional expert consultation on forestry education and training in the Caribbean. Advised on the current status of education and training in the region, potential areas of collaboration for regional institutions, and the feasibility of a regional forestry education network.

Haiti:

- Provided training and oversight for environmental assessments based on USAID Regulation 216.
- Provided environmental support and technical assistance to the USAID Haiti Mission Environment Program.

Jamaica:

- Participated at the Roundtable of Partners in Development in Kingston, Jamaica.
- Provided consultation to the Jamaica Forestry Department on the National Forest Management and Conservation Plan.

Events and Training

International Cooperation sponsors events and training for sustainable forest land management practices. In fiscal year 2002, related activities included:

- 11th Caribbean foresters meeting: Held jointly with the 7th Caribbean urban forestry conference in St. Thomas, U.S. Virgin Islands. It was attended by 168 participants from 16 countries, 2 U.S. territories, and 6 U.S. states. The conference addressed “The Future of Trees in the Caribbean: Biology, Planning, and Management.”

Conference participants considered ways to improve the urban forest ecosystem, focusing on the identification of mechanisms for the establishment and maintenance of increased tree cover in the urban environment.

Recommendations were made at the macro level of government, emphasizing the need to establish an appropriate land use policy that incorporates a legal framework for tree protection and management and a code of conservation ethics. It was furthermore noted that new, improved land use policy must be accompanied by the political will to enforce related laws and regulations.

Participants indicated that a change in government and public attitude toward urban forestry could be set into motion through the application of economic evaluations that reveal the positive effects of urban trees, in combination with related outreach and education programs. The need to supply sufficient resources for effective urban forestry activities was emphasized and, in turn, it was suggested that incentives (i.e., tax breaks) for tree maintenance and preservation should be developed and implemented. As a final point, it was agreed that policies should be put into place that mandate stakeholder participation in urban forestry development and activities.

Another set of recommendations was made at the micro level of government (i.e., individuals, natural resource related departments). First, participants emphasized the need to develop urban forestry legislation that facilitates integrated planning and implementation between associated institutions and that incorporates urban forestry activities into annual planning. The development and implementation of public awareness programs that focus on schools and community groups was strongly advocated. It was also suggested that in lower income urban areas, which traditionally have little if any tree cover, tree planting should be encouraged and facilitated.

On the technical side, it was agreed that specific training in urban tree management should be made available to the appropriate departments and personnel, and urban tree nurseries should be established based on identified needs of the target areas (species, size, site index). Finally, it was suggested that funding for these developments and activities could be supplemented by the private sector (influenced by tax breaks or other incentives, as mentioned above).

- Publication and distribution of the proceedings of the 10th Caribbean foresters meeting, which was held in Georgetown, Guyana, June, 2000. The meeting addressed the “Possibilities and Approaches Toward Community Forestry in the Caribbean” and was attended by 67 participants from 16 countries.

- Held the geographical information system, map projections and satellite image interpretation workshop in Puerto Rico, December, 2001, in collaboration with the Food and Agriculture Organization Subregional Office for the Caribbean. Thirteen representatives from Departments of Agriculture and Forestry and NGOs from 10 countries participated in the 4-day course. Course instructors included specialists from IITF, the U.S. Geological Survey Earth Resources Observation Systems Data Center, and The Nature Conservancy.

  The workshop focused on basic training in vegetation mapping and use of global positioning systems. It was also designed to encourage networking and continuity among the forestry departments of the Caribbean in relation to the many activities related to vegetation mapping.

English Equivalents

When you know:	Multiply by:	To get:
Hectares (ha)	2.47	Acres

Appendix: Recent Publications of the IITF, 2001-2002

01 Various authors. **1985–1999.** IITF silvics manual. SO-ITF-SM 1–88. Rio Piedras, PR: U.S. Department of Agriculture, Forest Service, International Institute of Tropical Forestry. Sectionally numbered. [Complete silvics manual available in English; has detailed silvicultural descriptions for 88 species of trees, e.g., *Swietenia macrophylla*, *Khaya senegalensis*, *Pterocarpus macrocarpus*, others]. [**Note**: this was translated into one volume in Spanish and is available as *Bioecología de árboles nativos y exóticos de Puerto Rico e Indias Occidentales*, traducido al español y disponible bajo este otro titulo, Gen. Tech. Rep. IITF-15].

02 Anderson, R.L.; Birdsey, R.A.; Barry, P.J. 1982. Incidence of damage and cull in Puerto Rico's timber resource, 1980. Resour. Bull. SO-88. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station, Institute of Tropical Forestry. 13 p.

03 Arendt, W.J. 1988. Range expansion of the cattle egret (*Bubulcus ibis*) in the greater Caribbean basin. Colonial Waterbirds. 11(2): 252-262.

04 Arendt, W.J.; Arendt, A.I. 1988. Aspects of the breeding of the cattle egret (*Bubulcus ibis*) in Monserrat, West Indies, and its impact on nest vegetation. Colonial Waterbirds. 11(1): 72-84.

05 Barres, H. 1964. Rooting media for growing pine seedlings in hydroponic culture. Res. Note 2. Rio Piedras, PR: U.S. Department of Agriculture, Forest Service, Institute of Tropical Forestry. 4 p.

06 Bauer, G.P.; Gillespie, A.J.R. 1990. Volume tables for young plantation-grown hybrid mahogany (*Swietenia macrophylla* x *S. mahagoni*) in the Luquillo Experimental Forest of Puerto Rico. Res. Pap. SO-257. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station, Institute of Tropical Forestry. 8 p.

07 Benstead, J.P.; March, J.G.; Pringle, C.M.; Scatena, F.N. 1999. Effects of a low-head dam and water abstraction on migratory tropical stream biota. Ecological Applications. 9(2): 656-668.

08 Birdsey, R.A.; Weaver, P.L. 1987. Forest area trends in Puerto Rico. Res. Note SO-331. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station, Institute of Tropical Forestry. 5 p.

09 **Birdsey, R.A.; Weaver, P.L.; Nicholls, C.F. 1986.** The forest resources of St. Vincent, West Indies. Res. Pap. SO-229. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station, Institute of Tropical Forestry. 25 p.

10 **Briscoe, C.B. 1962.** Crecimiento en diámetro de los árboles en los cerros de la región caliza seca. Apuntes Forestales Tropicales ITF-12. Rio Piedras, PR: U.S. Department of Agriculture, Forest Service, Tropical Forest Research Center. 2 p.

11 **Briscoe, C.B. 1962.** Tree diameter growth in the dry limestone hills. Trop. For. Note ITF-12. Rio Piedras, PR: U.S. Department of Agriculture, Forest Service, Tropical Forest Research Center. 2 p.

12 **Briscoe, C.B.; Nobles, R.W. 1962.** Height and growth of mahogany seedlings. Trop. For. Note ITF-13. Rio Piedras, PR: U.S. Department of Agriculture, Forest Service, Tropical Forest Research Center. 2 p.

13 **Chinea, J.D. 1999.** Changes in the herbaceous and vine communities at the Bisley Experimental Watersheds, Puerto Rico, following Hurricane Hugo. Canadian Journal of Forestry Research. 29(9): 1433-1437.

14 **Chinea, J.D.; Beymer, R.J.; Rivera, C.; Sastre de Jesus, I.; Scatena, F.N. 1993.** An annotated list of the flora of Bisley area, Luquillo Experimental Forest, Puerto Rico, 1987 to 1992. Gen. Tech. Rep. SO-94. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station, International Institute of Tropical Forestry. 12 p.

15 **Chudnoff, M.; Goytía, E. 1967.** The effect of incising on drying, treatability, and bending strength of fence posts. Res. Pap. ITF-5. Rio Piedras, PR: U.S. Department of Agriculture, Forest Service, Institute of Tropical Forestry. 20 p.

16 **Chudnoff, M.; Maldonado, E.D.; Goytía, E. 1966.** Solar drying of tropical hardwoods. Res. Pap. ITF-2. Rio Piedras, PR: U.S. Department of Agriculture, Forest Service, Institute of Tropical Forestry. 26 p.

17 **Crow, T.R.; Weaver, P.L. 1977.** Tree growth in a moist tropical forest of Puerto Rico. Res. Pap. ITF-22. Rio Piedras, PR: U.S. Department of Agriculture, Forest Service, Institute of Tropical Forestry. 17 p.

18 **Ding, M.M.; Brown, S.; Lugo, A.E. 2001.** A continental subtropical forest in China compared with an insular subtropical forest in the Caribbean. Gen. Tech. Rep. IITF-17. Rio Piedras, PR: U.S. Department of Agriculture, Forest Service, International Institute of Tropical Forestry. 46 p.

19 **Englerth, G.H.; Maldonado, E.D. 1961.** Bamboo for fence posts. Trop. For. Note 6. Rio Piedras, PR: U.S. Department of Agriculture, Forest Service, Tropical Forest Research Center. 2 p. [Disponible en español como Apuntes Forestales ITF-6].

20 **Ewel, J.J.; Whitmore, J.L. 1973.** The ecological life zones of Puerto Rico and the United States Virgin Islands. Res. Pap. ITF-18. Rio Piedras, PR: U.S. Department of Agriculture, Forest Service, Institute of Tropical Forestry. 72 p.

21 **Figueroa Colón, J.C.; Wadsworth, F.H.; Branham, S., eds. 1987.** Management of the forests of tropical America: prospects and technologies. Rio Piedras, PR: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station, Institute of Tropical Forestry. 469 p.

22 **Francis, J.K. 2000.** Estimating biomass and carbon content of saplings in Puerto Rican secondary forests. Caribbean Journal of Science. 36(3-4): 346-350.

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