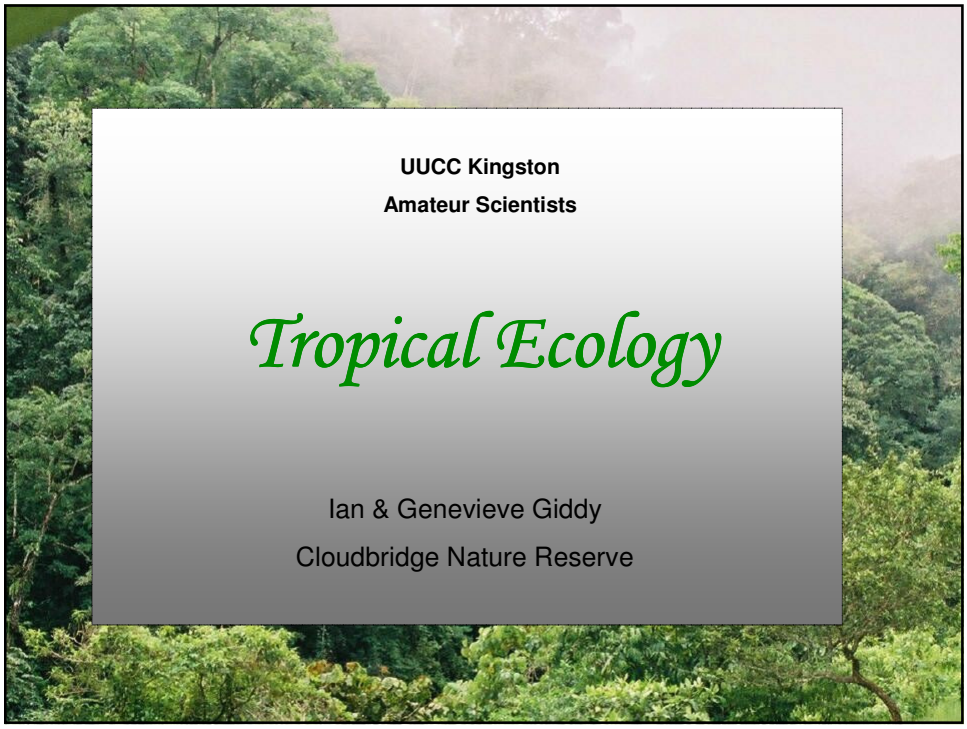
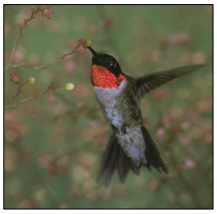
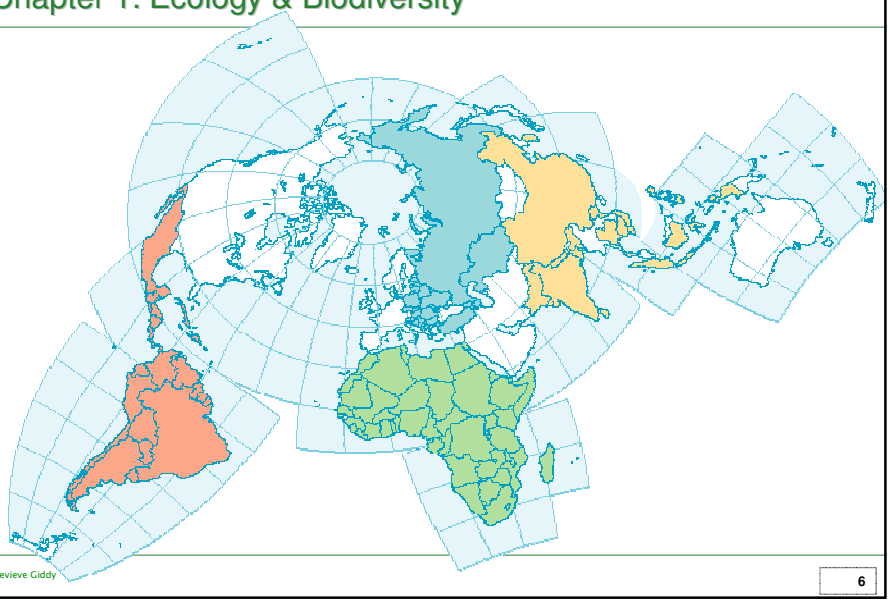


Tropical Ecology

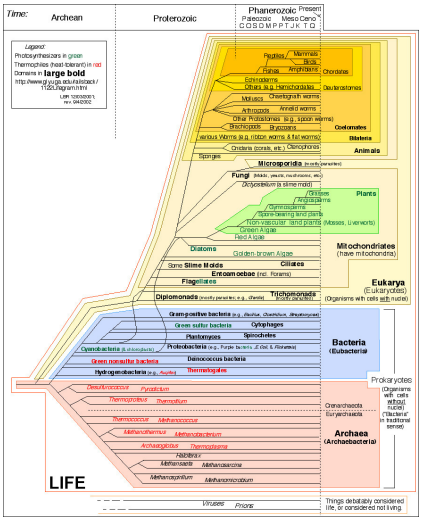
- Ecology and Biodiversity
- The Tropics
- Why Tropics = Biodiversity
- Research at Cloudbridge: a field study of tropical ecology
  - Part 1: Diversity
  - Part 2: Relationships
  - Part 3: Affirmative action
- A Modest Proposal



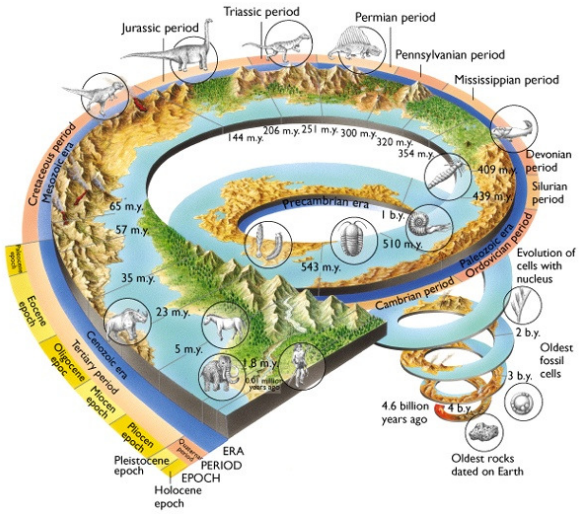
Chapter 1: Ecology & Biodiversity



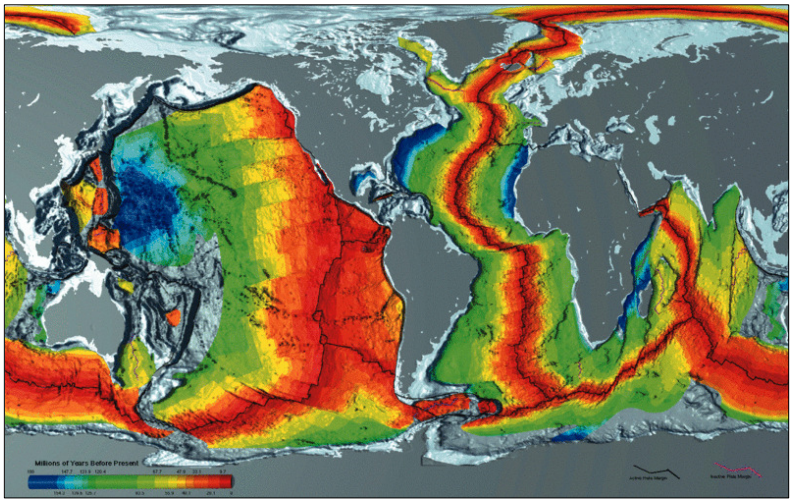
Recap: The Story of Life



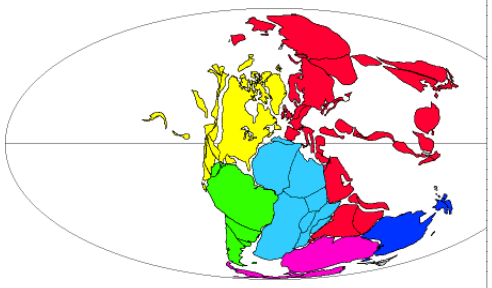
The Story of Life

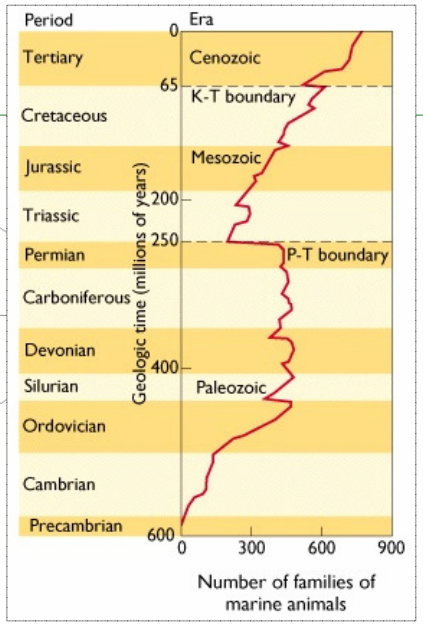


Recap: The Dynamic Earth

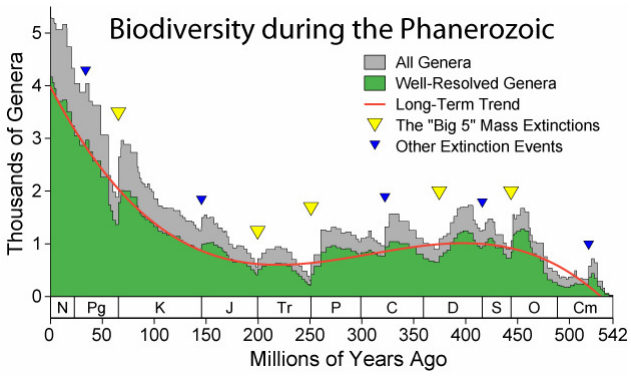


250 MYA: The Permian Extinction



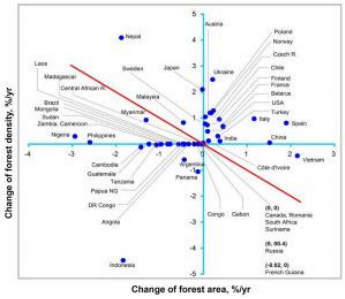


More Species Than Ever Before



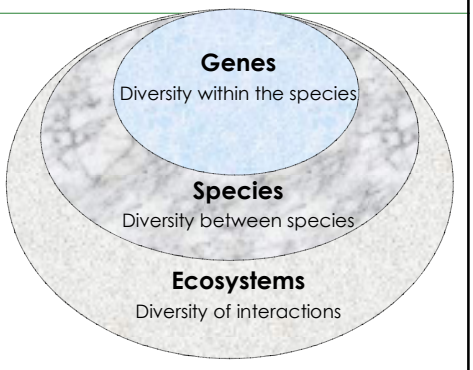
But Now, a Net Loss of Species

- Almost all scientists acknowledge that the rate of species loss is greater now than at any time in human history, with extinctions occurring at rates hundreds of times higher than background extinction rates
- Most of the species extinctions from 1000 AD to
- 2000 AD are due to human activities, in particular destruction of plant and animal habitats.



What is Biodiversity?

- A measure of the number of different forms of life, at three levels.
- UN: Biodiversity is "the variability among living organisms from all sources, including, *inter alia*, terrestrial, marine, and other aquatic ecosystems, and the ecological complexes of which they are part: this includes diversity within species, between species and of ecosystems".



A Common Currency

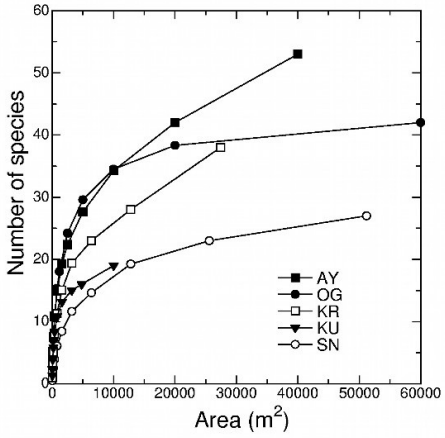
- One of the more broadly shared and economically defensible values for conserving wholesale biodiversity may be seen to lie in ensuring continued possibilities both for adaptation, and for future use by people in a changing and uncertain world.
- Consequently, biologists have argued that this value in biodiversity is likely to be associated with the variety of different genes that can be expressed by organisms as potentially useful phenotypic traits or characters (different chemicals, morphological features, functional behavior).
- Because we do not know yet precisely which genes or characters will be of value in the future, first they must all be treated as having equal value, and second, the greatest value for conservation will come from ensuring the persistence of as many different genes or characters as possible, as a form of insurance.
  - *For example, shield bug and a a giant tropical tree can be seen to represent a richer collection of characters in total, and so greater diversity value, than another pair of more similar species, like a dandelion and a daisy*

Ian & Genevieve Giddy

Measuring Biodiversity

- The simplest measure of biodiversity is species richness, S: the number of species in a given area.
- A simple version of the space-species relationship is:

$$S=cA^{x}$$



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Measuring Biodiversity

- A better measure is the Shannon-Weiner or "information index:"

$$H' = -\Sigma p \ln p$$

- Although this looks complicated it just means that for each species you determine the proportion (**p**) that it is of the whole, then multiply that number times the natural log (ln) of that number. This gives you **p ln p**. You do this for each species in the community then add up all of the resulting numbers. Since the number comes out negative we turn it into a positive number for convenience.

	Number of Individuals of Each Species in the Sample			
	Community 1	Community 2	Community 3	Community 4
species a	96	20	81	5
species b	1	20	1	5
species c	1	20	1	5
species d	1	20	1	5
species e	1	20	1	5
species f			1	5
species g			1	5
species h			1	5
species i			1	5
species j			1	5
species k			1	5
species l			1	5
species m			1	5
species n			1	5
species o			1	5
species p			1	5
species q			1	5
species r			1	5
species s			1	5
species t			1	5
S	5	5	20	20
H'	0.22	1.60	1.05	2.99

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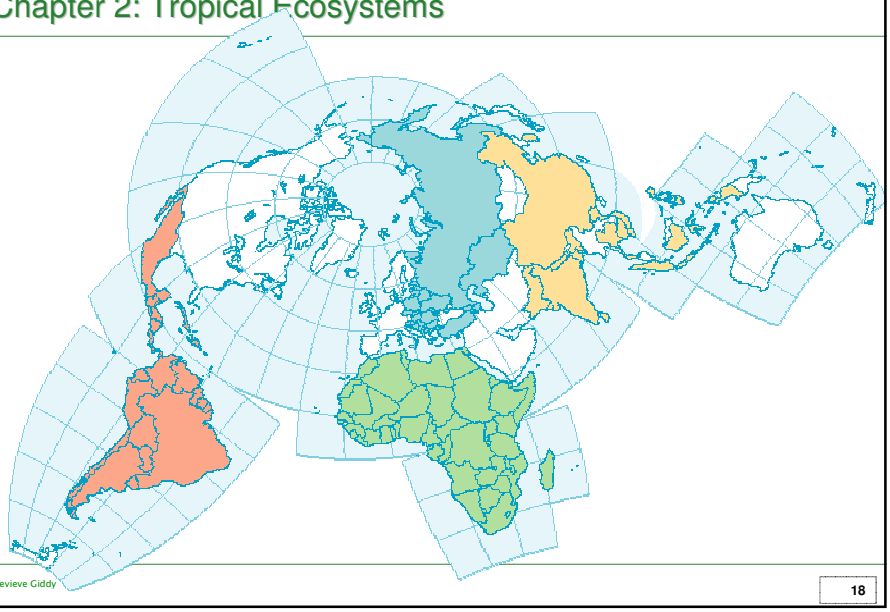
Chapter 2: Tropical Ecosystems



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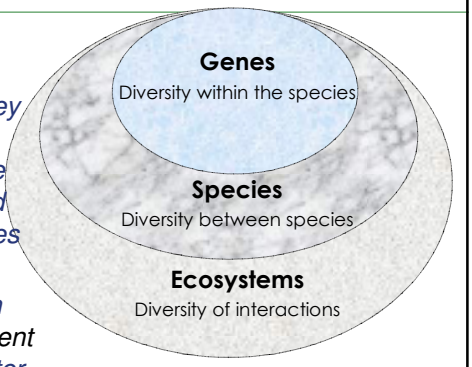
Ecosystems

- *"Ecosystems are communities of interacting organisms and the physical environment in which they live. Ecosystems are not just assemblages of species- they are combined systems of organic and inorganic matter and natural forces that interact and change.*
- *Ecosystems are intricately woven together by food chains and nutrient cycles; they are living sums greater than their parts. Their complexity and dynamism contribute to their productivity, but make them challenging to manage."*



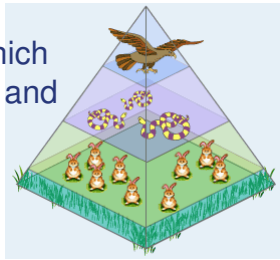
Ecological Factors

- Abiotic
  - Air, water, temperature, soil, light
- Biotic
  - Interspecific relations
    - ++ Mutualism (nectar and pollination)
    - +
    - 0 Neutral (lichen on leaves)
    - -
    - -- Parasitic (mistletoe in trees)
  - Intraspecific relations
    - Eg Suckling, competition for mates or food

"Food Chain" in an Ecosystem

- *Producers* -- usually plants which are capable of photosynthesis but could be other organisms such as bacteria around ocean vents that are capable of chemosynthesis.
- *Consumers* -- animals, which can be primary consumers (herbivorous), or secondary or tertiary consumers (carnivorous).
- *Decomposers* -- bacteria, mushrooms which degrade organic matter of all categories, and restore minerals to the environment.

In a food network, there will be fewer organisms at each level as one follows the links of the network up the chain.



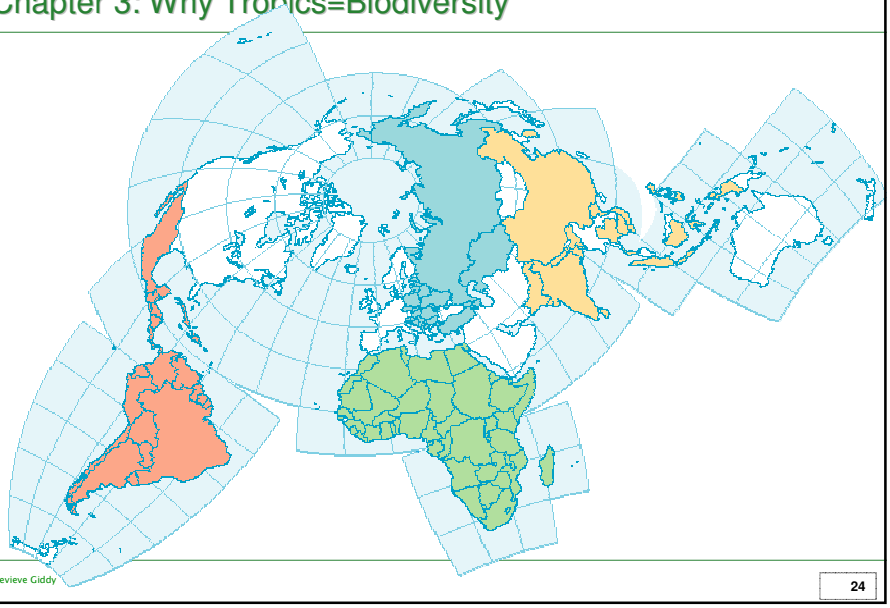
The Tropics

- The tropics are the geographic region of the Earth centered on the equator and limited in latitude by the Tropic of Cancer in the northern hemisphere, at approximately 23°30' (23.5°) N latitude, and the Tropic of Capricorn in the southern hemisphere at 23°30' (23.5°) S latitude. This region is also referred to as the tropical zone and the torrid zone.
- Tropical ecosystems may consist of rainforests, dry deciduous forests, spiny forests, desert and other habitat types. There are often significant areas of biodiversity and species endemism present particularly in rainforests and dry deciduous forests. Some examples of important biodiversity and/or high endemism ecosystems are: Costa Rican rainforests, Madagascar dry deciduous forests, Waterberg Biosphere of South Africa and eastern Madagascar rainforests.
- From "http://en.wikipedia.org/wiki/Tropics"

Tropical Nutrient Cycling

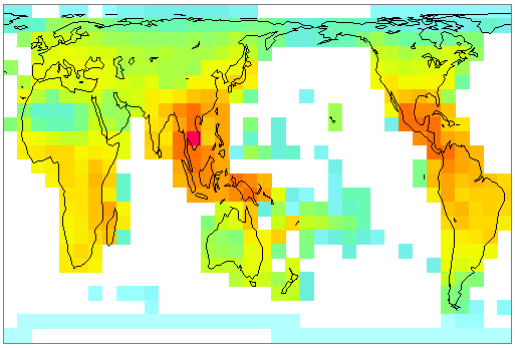
- In many tropical forests, the heavy rainfall tends to carry away nutrients; hence tropical rainforests have only been able to develop with the "invention" of very efficient nutrient cycling.
- The warm, moist conditions in the forest are ideal for the decomposers breaking down the remains of dead organisms. This quick decay returns the carbon and oxygen in the decomposing material to the air, and returns nitrogen, phosphorous, calcium, and other minerals to the soil. In the soil, the minerals are almost immediately taken up by a thick mat of plant roots and rootlike fungi.
- The fungi are known as mycorrhizae (literally "fungus-roots"); many of them form symbiotic relationships with plant roots. The mycorrhizae supply the plant with minerals and water; the plant returns sugars to the fungus. In some cases, the association between the plant and the fungus is so close that the fungal filaments (hyphae) actually penetrate the plant roots.
- In some cases, the root/fungal mat is so thick that there is direct nutrient cycling - nutrients move from dead organic matter into the roots without entering soil. In some rain forests in Venezuela these mats 15 to 40 cm thick and absorb 100% of the calcium and phosphorous
- Nutrient cycling occurs in almost every ecosystem; it's just better developed in tropical rain forests.

Chapter 3: Why Tropics=Biodiversity



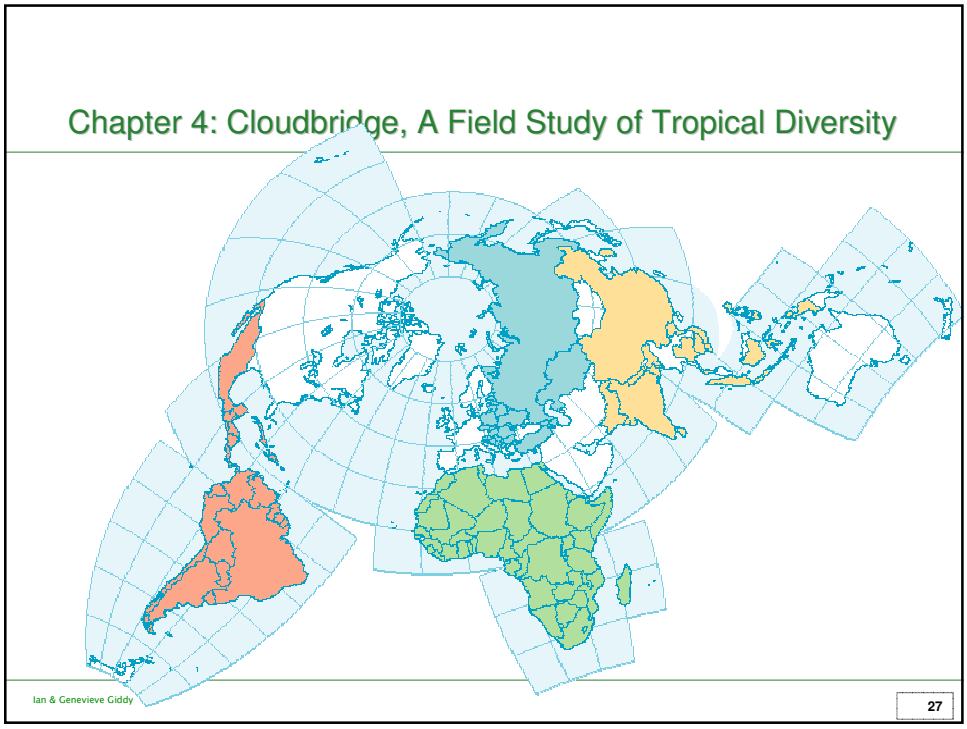
The Tropics Have More Biodiversity

- Darwin, Wallace and others observed what research confirms: there's more species diversity in the tropics.
- Biologists have struggled to explain this phenomenon.



Latitudinal Diversity Gradient: Explanations?

- Museum: the tropics have been there longer (geology)
- Cradle: the tropics are more fecund (climate)
- Long and productive growing season there, versus the short season in cold and arctic regions.
- Cradle or Museum? Both, it appears.


Chapter 4: Cloudbridge, A Field Study of Tropical Diversity
Ian & Genevieve Giddy
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Cloudbridge:
A private nature reserve
in Costa Rica

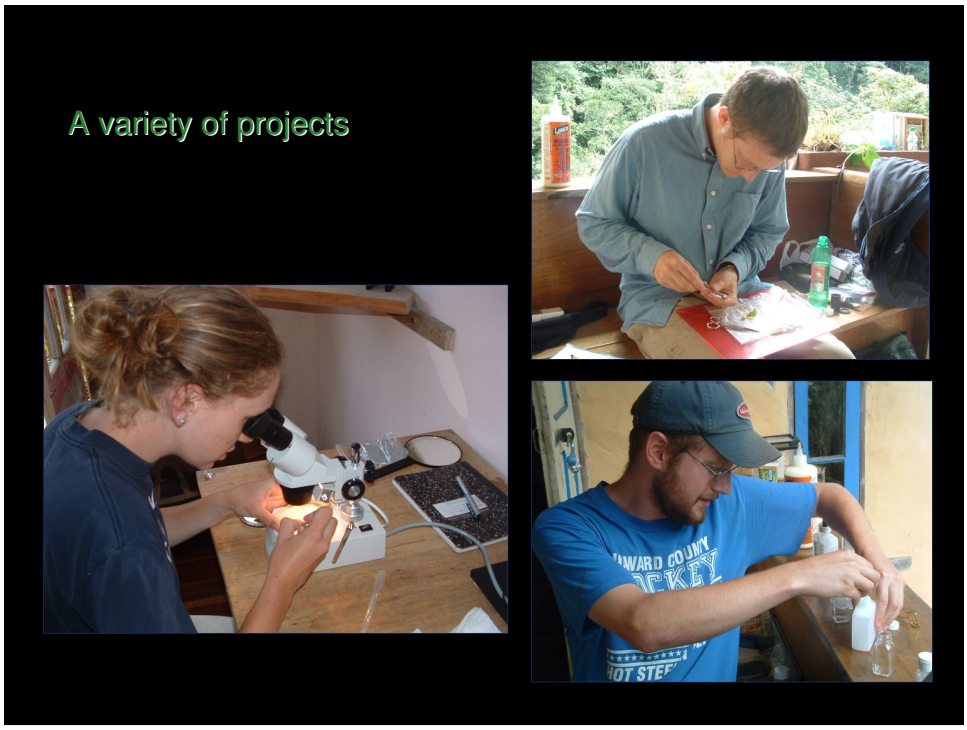
Lake Nicaragua
NICARAGUA
Salinas Bay
La Cruz
Upala
San Juan
Caribbean Sea
Liberia
CORDILLERA DE GUANACASTE
Boca Arenal
Santa Cruz
Cañas
Quesada
Guápiles
Nicoya
Siquirres
Puntarenas
Alajuela
Heredia
Irazú
Corina
Puerto Limón
SAN JOSÉ
Cartago
Turrialba
Tucurrique
Gulf of Nicoya
Nicoya Peninsula
Chirripó del Atlántico
Cabuya
Quepos
San Isidro
DE TALAMANCA
COSTA RICA
Dominical
Río Grande de Térraba
Buenos Aires
Coronado Bay
Golfito
PANAMA
North Pacific Ocean
Osa Peninsula
Gulf of Dulce

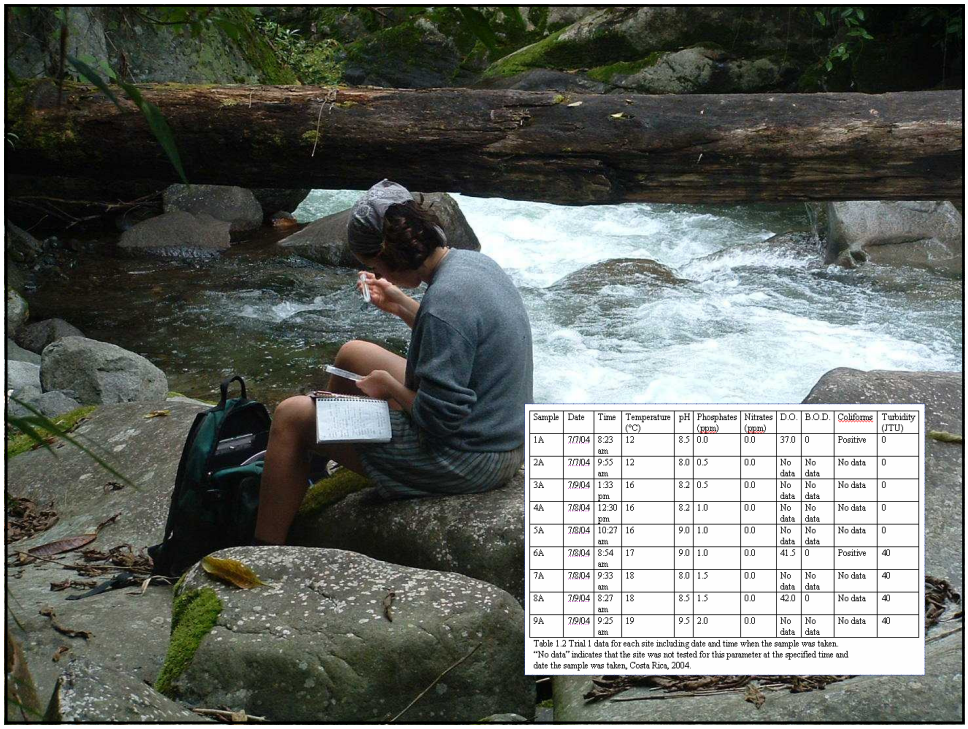
The goals of "Cloudbridge"
• Conservation
• Reforestation
• Education
• Research

Since 2002, Starting with Lichens

…insect collectors from Kansas – discovering a new species?

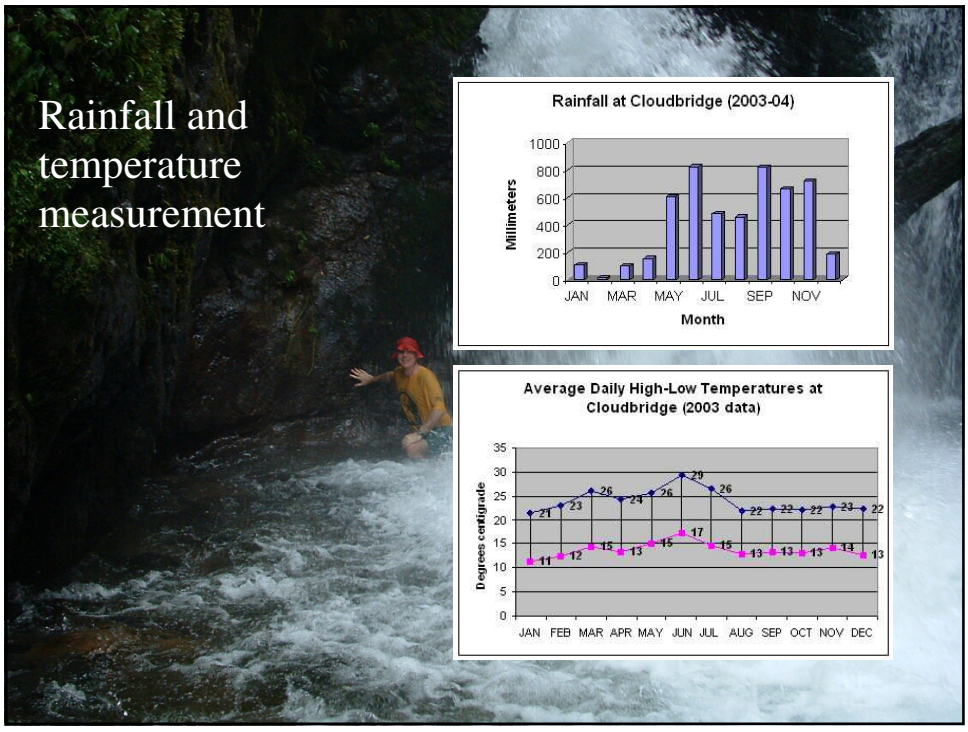
…and flora…


A variety of projects



Sample	Date	Time	Temperature (°C)	pH	Phosphates (ppm)	Nitrates (ppm)	D.O.	B.O.D.	Coliforms	Turbidity (JTU)
1A	7/7/04	8:23 am	12	8.5	0.0	0.0	37.0	0	Positive	0
2A	7/7/04	9:55 am	12	8.0	0.5	0.0	No data	No data	No data	0
3A	7/6/04	1:33 pm	16	8.2	0.5	0.0	No data	No data	No data	0
4A	7/6/04	12:30 pm	16	8.2	1.0	0.0	No data	No data	No data	0
5A	7/6/04	10:27 am	16	9.0	1.0	0.0	No data	No data	No data	0
6A	7/6/04	8:54 am	17	9.0	1.0	0.0	41.5	0	Positive	40
7A	7/6/04	9:33 am	18	8.0	1.5	0.0	No data	No data	No data	40
8A	7/6/04	8:27 am	18	8.5	1.5	0.0	42.0	0	No data	40
9A	7/6/04	9:25 am	19	9.5	2.0	0.0	No data	No data	No data	40

Table 1.2 Trial 1 data for each site including date and time when the sample was taken. "No data" indicates that the site was not tested for this parameter at the specified time and date the sample was taken, Costa Rica, 2004.



On The Web

Reports on Research at Cloudbridge

[Espanol]

1 Research Opportunities
2 Rainfall and Temperature
3 Habitat Photomonitoring
4 Habitat Biomonitoring
5 Reforestation Monitoring
6 Lichens
7 Water Quality
8 Benthic Macroinvertebrates
9 Bird Sightings
10 Birdlife Monitoring

11 Cloudbridge Land Use Study
12 Moss Recovery
13 Bromeliads
14 GIS Studies
15 Tree Diversity
16 Heliconia Pollination by Hummingbirds
17 Forestry Economics
18 Sustainable Use of Forest Resources
19 Mycorrhizae
20 Forestry Methods at Cloudbridge
21 Winged Insect Diversity
22 Insects of Cloudbridge
23 Owl Distribution
24 Small Mammals
25 Chirripo Valley Land Use Study
26 Smithsonian Global Biomonitoring Study

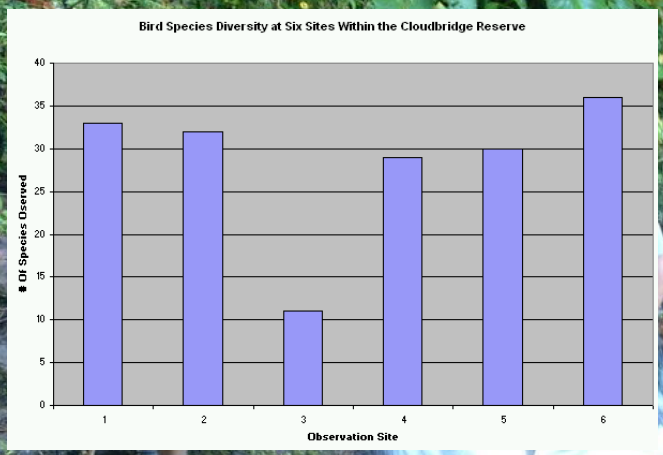
Google Calendar (Click on this calendar to see the schedule of volunteers and researchers)

Home | Ecology | Project | Nature Notes | Site Map | Contact

Tropical Ecology Research at Cloudbridge

- Diversity
- Relationships
- Affirmative Action

Diversity: Of Birds and Trees



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Diversity: Of Birds and Trees

Cloudbridge Tree Species Identification and Distribution Project - known species list

The study area is a 20m x 60m area in the Cloudbridge Reserve situated at an average height of 1755 meters and located west of and adjacent to Chirripo National Park in central Costa Rica. The area appears to be virgin forest with the oldest trees estimated at several hundred years old. The area is on a 30° to 40° slope facing west.

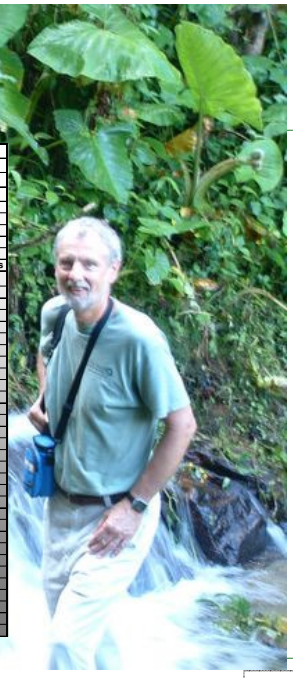
There are a total of 78 trees in the study area, including an estimated 59 species.

Fifty of these 59 species have only one member in the study area.

We have identified 22 of these 50 species (listed below). We were unable to identify the remaining 28.

We have identified 6 of the 9 species with multiple members in the study area (listed below).

Local name *	Family	Genus	Species	N	References
Known species with only a single member in the study area					
	Actinidiaceae	Saurauia	pittieri	1	H, SV
Peine de mico	Elaeocarpaceae	Sloneа	ampla	1	H, SV
Cristobal	Fabaceae	Dalbergia	sp	1	F
Ira	Lauraceae	Ocotea or Nectandra	sp	1	H, G, F
Quizarra	Lauraceae	Ocotea or Nectandra	sp	1	H, G, F
Ira amarillo	Lauraceae	Ocotea or Nectandra	sp	1	H, G, F
Ira rosa	Lauraceae	Ocotea or Nectandra	sp	1	H, G, F
Ira	Lauraceae	Ocotea or Nectandra	sp	1	H, G, F
Ira blanco	Lauraceae	Ocotea or Nectandra	sp	1	H, G, F
	Lauraceae	Ocotea	sp	1	H, SV
Yas	Lauraceae	Persea	schiedeana?	1	H, G
Lengua de vaca	Melastomataceae	Conostegia or Miconia	sp	1	H, G
Cedro dulce	Meliaceae	Cedrela	tonduzii	1	H, G
Cocora	Meliaceae	Guarea	sp	1	
Uruca	Meliaceae	Trichilia	havanensis?	1	H, G, F, FO
	Moraceae	Brosimum	sp	1	H, SV
	Myricaceae	Morella	sp	1	SV
	Myristicaceae	Otoba	sp	1	SV, FO
	Rubiaceae	Elaeagia	auriculata?	1	H, G, SV
	Sabiaceae	Meliosma	vernicosa?	1	H, G, SV
Burio	Tiliaceae	Heliocarpus	americanus	1	H
Tirra	Ulmaceae	Ulmus	mexicana	1	H,G, F
Known species with multiple members in the study area					
Papayo	Araliaceae	Oreopanax	xalapensis (FO)	5	H,G
Surtuba	Arecaceae	Geonoma	edulis	4	H
Helechon	Cyatheaceae	Alsophila	cuspidata	5	G,R
Nispero	Euphorbiaceae	Croton (FO)	sp	2	SV
Poro	Fabaceae	Erythrina	poeppigiana/costaricensis (FO)	3	H, G
Lengua de vaca	Melastomataceae	Conostegia	sp	3	H, G



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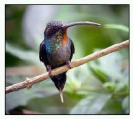
Relationships

Do Sympatric Heliconias Attract the Same Species of Hummingbird?
Observations on the Pollination Ecology of *Heliconia beckneri* and *H. tortuosa* at Cloudbridge Nature Reserve

Joseph Taylor
University of Glasgow

where hermits are absent (Stiles, 1979).

The Violet Sabrewing was only seen to visit inflorescences of *H. beckneri* at one large clump in secondary growth during trial observations. *H. beckneri* flowers had on average significantly higher energy content (Table 2 below) but it may be the case that differences in the width of the corollas (Snow and Snow, 1972; Temeles *et al.*, 2002) make feeding at *H. beckneri* flowers less energetically efficient for this species. The Violet Sabrewing may have an innate attraction to the red bracts or yellow flowers of *H. tortuosa*. Perhaps the presence of the Green-crowned Brilliant as the principal visitor to flowers of *H. beckneri* alters the preferences of the Violet Sabrewing.



The **Green Hermit** visited flowers of both species, although the mean visitation rate was higher at flowers of *H. beckneri* perhaps because of the significantly higher mean energy content of *H. beckneri* flowers (Table 2). The Rufous-tailed Hummingbird was uncommon on the reserve and was not seen to visit either *Heliconia* species. This hummingbird species occurs locally up to an elevation of 1850m (Stiles and Skutch, 1989), which may explain the scarcity of this species at Cloudbridge.

The pollination services of the Green Hermit were partitioned between the *Heliconia* species. Males accounted for 92% of all flower visits at clumps 3-7 of *H. beckneri*, while 96% of all flower visits at *H. tortuosa* were by females or juveniles. This may be due to the interaction of a dominance hierarchy and a difference in the energy content of flowers, as female hummingbirds are generally subordinate (Stiles, 1976).

Why do the hummingbirds favour different species of *Heliconia*? To gain an insight into this issue, we examined some aspects of the two plant species and how they matched differences between the hummingbirds. First, the *Heliconia* species had significantly different nectar contents. Measurements of accumulated nectar at 06:00 and 12:00 revealed that at both of these times there was a significantly higher mean volume of nectar in the flowers of *H. beckneri* compared with those of *H. tortuosa* (Table 2). The mean percentage sugar concentration and sugar content of nectar were significantly higher in *H. beckneri* at 06:00 compared with *H. tortuosa*, but the higher mean sugar content and concentration in *H. tortuosa* flowers at 12:00 did not represent a significant difference. As a result mostly of the difference in nectar volume, the mean total energy content (J) of flowers was significantly higher in *H. beckneri* at both 06:00 and 12:00. It is assumed that differences in the mean temperature and relative humidity measured at picking and dissection only had a minor influence on the volume of accumulated nectar, but may account for differences in the concentration of nectar.

Table 2. Mean nectar volume (µl), percentage sugar concentration (refractometer reading), sugar content of nectar (mg µl^{-1}) and energy content (J flower^{-1}) in flowers of *Heliconia beckneri* and *H. tortuosa* at Cloudbridge Nature Reserve in June and July 2001. The results and significance of Mann-Whitney *U*-tests are displayed for each species comparison. SD = standard deviation. *N* = 10 flowers at each sampling time for both species.

Variable	Time	*H. beckneri* Mean	*H. beckneri* ± 1 SD	*H. tortuosa* Mean	*H. tortuosa* ± 1 SD	Mann-Whitney *U*	*P*
Volume (µl)	06:00	61	56	20	14	139.5	0.010**
	12:00	141	91	41	32	72.0	0.014**
Percent sugar*	06:00	21.3	5.2	18.5	4.8	137.0	0.017**
	12:00	21.2	1.6	22.4	4.7	85.0	0.135
Sugar content (mg µl^{-1})	06:00	0.2330	0.0588	0.2003	0.0543	137.0	0.017**
	12:00	0.2302	0.0186	0.2453	0.0547	85.0	0.135
Energy content (J flower^{-1})	06:00	248.82	237.58	74.22	53.98	138.0	0.014**
	12:00	556.80	358.78	183.28	155.87	136.0	0.021**

* °Brix. % mass sucrose equivalents.
** Significant if $P < 0.05$

Another aspect we studied was the morphology (shape) of the birds' bills and their match with the morphology of the *Heliconia* flowers. Surprisingly, the mean total and effective corolla lengths of the two *Heliconia* species were identical (58mm and 36mm respectively), with very similar ranges. What differed was the curvature of the flowers. Those of *H. beckneri* have a slight curvature just before the nectar chamber, while flowers of *H. tortuosa* have a moderate, even curvature throughout the length of the corolla (Figure 2).

Figure 2. Three fresh flowers of *Heliconia tortuosa* (left) and *H. beckneri* (right) with millimetre scale.

The difference in flower curvature forced birds to feed from different angles and thus pollen was probably deposited on different parts of their bodies. At *H. beckneri* flowers Green Hermits and Violet Sabrewings inserted their bills from in front of the flowers, probably resulting in the anthers and stigma touching their lower mandible and chin. However, at *H. tortuosa* flowers these species inserted their bills from above and behind the flowers, sometimes at an angle, so that the anthers and stigma probably touched the upper mandible, forehead and crown. Interspecific pollen transfer might result in the hybridisation of *H. tortuosa* and *H. beckneri*, since *H. tortuosa* is known to hybridise with *H. lanipanha* (Stiles, 1979), one of the probable parent species of *H. beckneri* (Daniels and Stiles, 1979; website 2). However, the differences in the probable pollen deposition sites are likely to reduce the risk of pollen loss and cross-fertilisation.

In conclusion, any competition for pollinators between these *Heliconia* species at Cloudbridge is lower than predicted by the shared pollinator identities given by Stiles (1979). The flowering of *H. beckneri* and *H. tortuosa* are both predicted to be at peak early in the rainy season (Daniels and Stiles, 1979), thus there is no evidence of a change in their flowering

Affirmative Action

Annual Monitoring of Habitats and Tree Recovery

Reforestation Monitoring Study
Kate Moss et al

Reforestation Monitoring: The Study

This is an ongoing study of the Cloudbridge reforestation effort. Each year, starting in 2003, we monitor a substantial sample of the trees that have been planted, to assess their growth and health. We are seeking volunteer researchers to continue with this project.

Reforestation Monitoring: Methodology

Originally designed by Kate Moss

The purpose of the data collected on planted tree sites is to give an evaluation of each site and to start compiling a database on the conditions preferred by different tree species. Information concerning slope, competition, coverage, soil quality and drainage was collected along with the tree species (if known) and tree condition. At the same time sites were numbered and labeled so that specific sites could be revisited in the future.

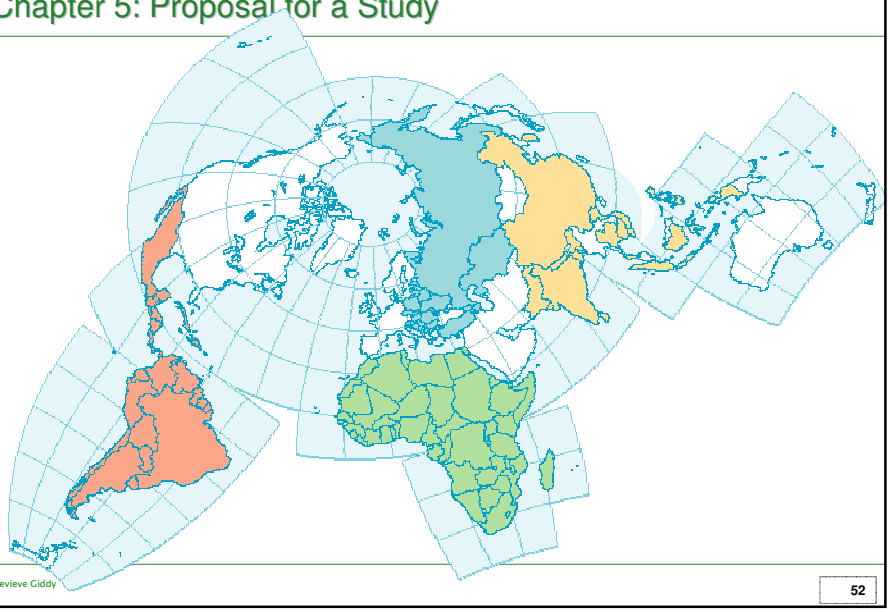
The labels: Metal tags were affixed to the stake corresponding to tree site. The tree number, species and date planted were engraved into the tag. At the beginning another number corresponding to the number of the specific species planted (similar to the number of tree but only the number of trees of that species) was also included but later dropped as deemed unnecessary. The labels now read tree number, species, date. For example: [134 CY 02] would indicate tree number 134 is a Cypress planted in 2002. If species or date are not know than that space is left blank. Metal tags are first etched with a ball point pen and then retraced with a black permanent marker. This creates a much longer lasting label than just permanent marker. Between tree 200 and 300 we ran out of metal tags and started using orange flagging tape. This flagging tape is always tied below that corresponding to the date as not to get the two confused. It is important that these tags soon be replaced with metal tags so that a more secure marker be in place.

Tree number: Sites (with or without trees) that are deemed good for planting (for example, if is a site is located under another tree it is not good for planting and should be excluded) are given a tree number. If there is no tree or if the tree is dead this should be noted in the additional section so that one may be planted there later. In the tree number column it is also important to note the tree species and date it was planted.

The following are the measures we take for each tree:

Tree height:	The height in meters beginning at the base to the top of the crown with measuring stick or Abney See separate Abney Guide. Picture of Abney Level below (Stephan used Blume-Leiss device)
DBH (diameter at breast height)	The stem diameter at the height of 1.3 m in cm with measuring tape or caliper (cross measuring)
Crown Diameter:	The crown radius in 4 cardinal directions in meters with measuring stick or measuring tape

Chapter 5: Proposal for a Study



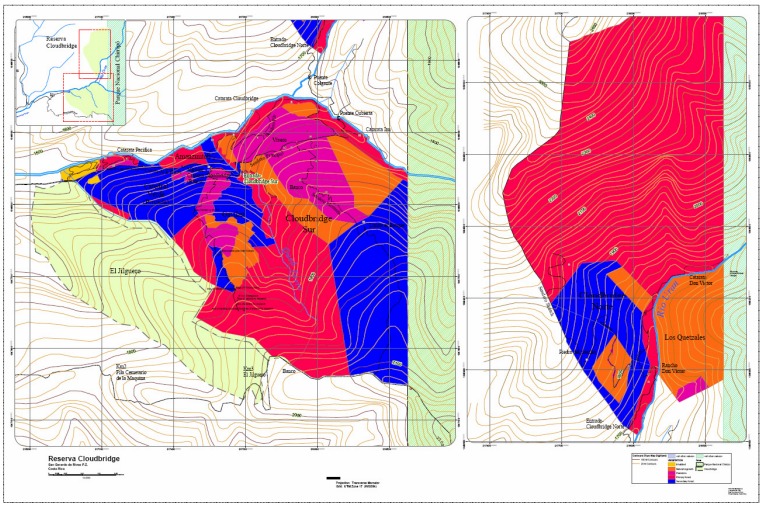
Restoration Ecology

- Restoration ecology can be viewed as the study of how to repair anthropogenic damage to ecological systems.
- Ecological characteristics have been considered as restoration goals, for example reinstating the plant and animal **species** originally found at the site.
- Much less emphasis has been placed on ensuring that ecological **processes** are reinstated, although the persistence of the restored system ultimately depends upon these processes.
- These processes include the restoration of food web relationships, interactions with mutualists such as pollinators and seed dispersers, decomposition processes and nutrient cycling.

Restoration at Cloudbridge: Affirmative Action or Natural?

- Active reforestation seems to be promoting a healthier new forest than non-interventionist, shrub-dominated recovery of disturbed areas.
- But is an *ecosystem* being restored? And how does this compare with secondary and primary forest?

Vegetation Cover



The Proposal

- Compare the two methods of regeneration (planting and natural regeneration) with primary and secondary forest plots to assess the efficiency of alternative approaches to increasing the diversity and abundance of a broad range of taxa.
- What structural and functional components of the recovering forest are necessary to meet the needs of the returning fauna and flora and how and when do the newly growing trees met those needs?
- Time-to-recovery and successional patterns will be assessed by monitoring within the treatments. This will allow us to form an understanding of the mechanisms of recovery. For example, are some species necessary in the area before others can colonize?

	Method of Restoration	
	Reforestation	Natural regeneration
Existing forest	Primary	Secondary

Further exploration

- giddy.net/tropicalecology
- John Kricher, *A Neotropical Companion*
- Ken Miyata, *Tropical Nature*
- cloudbridge.org

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