

THE SIGEO-CTFS ARTHROPOD INITIATIVE

Background

More than 25 years ago the **Smithsonian Tropical Research Institute** (STRI) established a large-scale forest research plot on 50 hectares of lowland tropical forest on **Barro Colorado Island** (BCI), in Panama. Within the plot, every free-standing tree with a diameter at breast height of at least 1 cm was tagged, measured, mapped, and identified to species. The large scale and standard forest census methods developed on BCI proved to be a powerful approach to studying the dynamics of tropical forests. By 1990 scientists around the world had replicated the STRI methods, and a global network of research plots emerged.

The network was initially named the **Center for Tropical Forest Science** (CTFS; <http://www.ctfs.si.edu/>) and although administered by STRI, individual forest plots are led and managed in each country by one or more partner institutions. CTFS coordinates research activities using standardized methods on forest plots ranging from 2 – 52 hectares that now include **22 sites in 15 tropical countries** in Latin America, Africa, and Asia. This international collaboration is now monitoring the growth and survival of 3.5 million trees in over 6,500 species – over 12% of all known tropical tree species. The CTFS system has now matured to the point where there is a tremendous and unique opportunity to expand the program into a truly interdisciplinary research endeavor that will enable the world's scientists to investigate key indicators of global environmental health.

The Smithsonian Institution is now in the process of transforming its network of tropical forest plots into the **Smithsonian Institution Global Earth Observatories** (SIGEO, <http://biogeodb.stri.si.edu/bioinformatics/sigeo/>). This will include three main approaches: (a) a global carbon research program will provide in situ measures of above- and below-ground carbon and how it is changing in response to rising CO₂; (b) the establishment a series of large-scale temperate plots that will permit direct comparison to the expanding tropical plot network; and (c) **expanding the tree monitoring program** by assessing the impact of global change on biodiversity through focused surveys of vertebrates, invertebrates, and microbes across the Global Earth Observatories. Item (c) includes an **arthropod initiative** that will monitor key assemblages over long-term and study insect-plant interactions over the SIGEO network.



Map showing the 22 established SIGEO sites in black (black dots) and 12 candidate sites in blue (red dots).

[CRC = Smithsonian Institution Conservation & Research Center; SERC = Smithsonian Environmental Research Center]

The SIGEO-CTFS arthropod initiative: rationale

Arthropods represent the most diverse group of terrestrial organisms on the planet. They play crucial roles in forest dynamics, such as **herbivory**, **seed predation**, **pollination**, **parasitism/mutualism**, **decomposition** and **nutrient cycling**. The CTFS plots, with their global biogeographic coverage and detailed local spatial data on the tree communities over large areas, provide a unique opportunity to address fundamental questions about the structure and dynamics of arthropod communities, and their functional roles. The new arthropod initiative was developed by an international team of 26 experts (full report available on request). It will integrate with ongoing monitoring of plant dynamics within the CTFS network, cause minimum possible impact to the plots and focus on a priority set of assemblages chosen for their ecological relevance, taxonomic tractability and ease of sampling. These include: **termites** (decomposers), selected **moths and butterflies** (herbivores, pollinators), tephritid **fruit flies** (fruit feeders), litter-dwelling **ants** (various roles), **bees** (pollinators, pollenophages), selected **parasitoids**, and **seed predators**. The first year of the program should be devoted to a **'baseline' survey** to serve several purposes, notably:

- (a) developing taxonomic and other partnerships, establishing initial inventories of each priority assemblage, and constructing a molecular barcode library for target taxa;
- (b) obtaining estimates of diversity and taxonomic composition for basic pattern analysis across the participating CTFS;
- (c) comparing local and regional arthropod pools across sites; and
- (d) refining the methodology and the definitive choice of assemblages, or subsets of them.

This baseline survey will involve replicated, repeated sampling programs using light traps (moths, termites and other assemblages), Winkler extraction of litter (ants), McPhail traps (fruit-flies), colony census and baits (bees) and transect sampling for termites and butterflies (i.e., based on a mixed set of procedures). **'Key' comparisons among CTFS sites** for priority assemblages should be organized along key gradients viz. **Biogeography** (Neotropics vs. Afrotropical vs. Oriental), **rainfall seasonality** (mainland Asia), and **fertility/productivity** (Neotropics). These comparisons should involve more intensive sampling of priority assemblages within selected sites, subject to availability of funding.

This baseline survey will be followed by longer term programs of field work and analysis, organized into two main sub-programs: **monitoring**, and key **interaction studies**. The monitoring sub-program will be directed to detecting long-term changes, as reflected in priority assemblages, driven by climatic cycles, climatic change and landscape scale habitat alteration. Methods will be similar to those used in the initial baseline survey, but with lower sampling intensity. An understanding of the interactions between arthropods and plants is essential to an understanding of the dynamics of the forest community as a whole. Changes in interactions can also be as sensitive or even more sensitive indicators of long-term changes than changes in species richness or abundance. A sub-program of process studies should, therefore, be carried out at selected sites based on key vegetation-related interactions. This **food web approach** should in particular include:

- (a) studies of host specificity and parasitism within the Lepidoptera using caterpillar rearing and barcoding analyses;
- (b) comparisons of herbivore assemblages associated with target tree species within and across sites, designed to answer important questions: viz. differences between herbivore assemblages on closely related tree species across sites, the role of plant phylogeny in determining herbivore species richness, the role of plant functional traits in determining herbivore load and diversity;
- (c) the nature and rate of seed predation based on rearing programs of seeds collected occasionally and/or in a subset of the pre-existing seed traps, and;
- (d) the impact of leaf litter characteristics (composition, amount, chemistry) on the composition of the associated arthropod assemblage, particularly ants.

Such studies will be initiated on a small subset of local plant species (such as perhaps ten focal tree species). When deemed appropriate, a new subset of focal plant species will be chosen, **expanding progressively the study system** and the **ecological knowledge of CTFS plots**. The main questions addressed by the interaction studies and monitoring program have deep implications for ecological theory, for example:

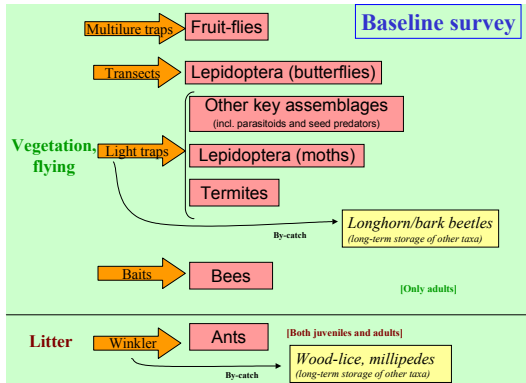
- (a) does insect diversity, composition or abundance vary more in space or time at more diverse or more heterogeneous CTFS plots?
- (b) how is variability in food web structure ('connectivity' and other measures of insect interaction structure and relative insect abundance, including host-specificity) affected by the phylogenetic structure of plant communities (formed from different regional species pools), rainfall and productivity?
- (c) what are the relative importance of plant phylogeny and functional traits in shaping the abundance and diversity of herbivore and detritivore communities?

As far as possible, further externally-funded studies should be invited to exploit the special opportunities provided by the CTFS plots. The arthropod program will require a vigorous **training component** dedicated to local **capacity building** (training

parataxonomists or students), educational development (participation of local CTFS plot partners, arthropod PIs and their students) and **technology transfer** (e.g. DNA barcoding).

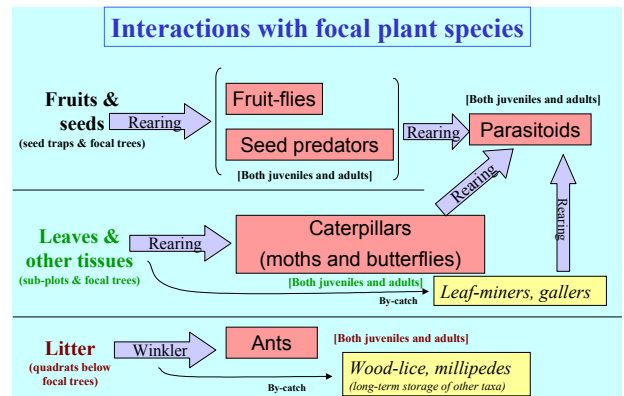
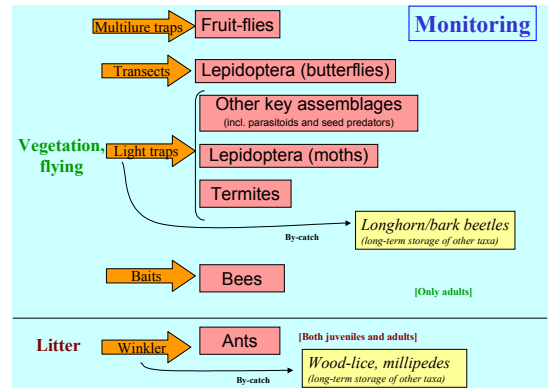
Pilot study, tuning of protocols
Focus: adults (traps)

Derived protocols
 from baseline survey
 adults, traps



Year 1

Juveniles reared from
 focal plant species



Years 2-n

Outline of the monitoring and interactions sub-programs. Since adults are easier to survey than juveniles, the monitoring scheme targets adults, surveyed by traps. Since juveniles are often more intimately associated with plants than adults, interaction studies focus mainly on juveniles reared from focal plant species. The baseline survey, reference collections and barcoding library will help to match juveniles with adults.

Activation of the initiative and the near future

In 2008 CTFS will provide **seed money** to start implementing the initiative at **Barro Colorado Island, Agua Salud** (Panama) and **Khao Chong** (Thailand). Specifically this funding will allow (a) performing the **baseline survey** in full on BCI: litter ants, selected moths, butterflies, bees, termites and fruit-flies (seed predators, parasitoids and caterpillars are not targeted in this initial effort but will be studied when starting monitoring and interaction studies in 2009); (b) survey likewise at Agua Salud litter ants, butterflies, bees and fruit-flies; and (c) survey butterflies, bees and fruit flies at Khao Chong. In addition, the Environmental Protection Agency (EPA) is funding **mosquito** monitoring at BCI, Agua Salud and Khao Chong and will work closely with the arthropod initiative.

Agua Salud represents a series of **forestry treatments** (with the aim of optimizing timber production, not biodiversity) north of Pipeline Road, near Gamboa. As such, the treatments provide an opportunity to survey levels of biodiversity, monitor arthropod species and insect-plant interactions and compare results to those obtained in relatively undisturbed forest nearby (i.e., BCI). In 2008, the arthropod initiative will initiate baseline surveys at four treatment plots: **control forest, natural succession, teak plantation and optimal reforestation treatment**. In essence, arthropod studies at Agua Salud will represent a **large-scale pilot study** comparing disturbed versus undisturbed forest habitats, which could be replicated elsewhere in the SIGEO-CTFS network of plots.

In the near future, we hope (a) to **consolidate** and **expand** arthropod studies at BCI, Agua Salud and Khao Chong; and (b) to expand the arthropod initiative to **other and future CTFS plots**, pending on both additional funds available to us and interest of local plot PIs. Such potential plots may include **Wanang** (Papua New Guinea), **Ranomafana** (Madagascar), the Smithsonian **Conservation and Research Center** at Front Royal, Virginia, USA

(<http://nationalzoo.si.edu/ConservationAndScience/CRC/FrontRoyal/>) and the **Smithsonian Environmental Research Center** at Edgewater, Maryland, USA (<http://www.serc.si.edu/>), as well as other plots in China, Philippines, Colombia and Singapore.

In-site implementation at BCI, Agua Salud and other plots

There are very few successful insect monitoring programs in the tropics, apart from those directed to specific pests. One of the main challenges is the long-term processing and identification of countless number of species, which tend to wear both staff and budget of even the largest institutions (T. Erwin, pers. comm.). The experience accumulated by Basset, Miller and colleagues during three insect projects in Papua New Guinea, Guyana and Gabon over 19 cumulative study years lead us to propose a different strategy for particular plots. In Panama, this approach will involve a **site coordinator** training **local parataxonomists**. For other plots, **other strategies** may need to be implemented (see below).

The first study year will represent both a pilot study of different protocols and a baseline survey, during which parataxonomist staff will be trained. Monitoring per se and interaction studies, as agreed by the CTFS arthropod workshop group, would start after refining protocols, during the second year. The baseline survey (and subsequent derived protocols for monitoring) would target only particular insect groups collected by particular methods that can be applied consistently over the network of CTFS plots. Hence, we will target **common species** that are **well collected** with **consistent methods**, which is reasonable as rare species will not be amenable to statistical analysis of long-term monitoring trends.

Taxonomists associated with the arthropod initiative will be asked to provide **taxonomic feedback** to the parataxonomists so that the latter may be able (perhaps with additional **barcoding** information for cryptic species) to identify the most common insect species collected in their surveys. This will be achieved by preparing **local reference collections**. In essence, after adequate taxonomic feedback and **quality control** (which may vary between arthropod focal groups), the parataxonomists should be able to monitor themselves common insect species. Thus, taxonomists will not be flooded with an endless supply of similar material. Rather, their interest will be kept alive from the study of a **varied insect material** resulting from the interaction studies and the **rotation of focal tree species** within the CTFS plots.

Working with **students** is rewarding in the short-term but not in the long-term as they invariably leave to pursue their careers, and training needs to be resumed with different staff (note that this may also be the case for well-trained parataxonomists but the momentum is longer in this case). In Panama, students will not be involved in the monitoring sub-program of our initiative, but rather in additional and **more rewarding research activities** within the plots and in the interaction studies sub-program of our initiative. In Panama, there will be ample opportunities for collaboration with the Maestria de Entomologia of the National University. We are also hoping to attract the interest of entomologist colleagues and their students from U.S.A. or Europe, to be involved either in Panama or elsewhere in the SIGEO- CTFS network.

Our implementation strategy will need to be modified at locations where **student training** is more feasible or sought after. In addition, the situation for future temperate plots in the U.S.A. or Europe is entirely different, for three main reasons: (a) high salaries precluding local employment; (b) presence of **local entomological societies**, often backed up by local museums or academic institutions; (c) lower insect diversity than in the tropics. Item (b) is significant, as members of these societies may be keen **to team up on a volunteer basis** to a collaborative project supervised by in-country entomologists. It probably represents the best option of implementing the SIGEO- CTFS arthropod initiative (or part of it) at future U.S. or European plots.

Benefits of the SIGEO-CTFS arthropod initiative

Apart from the more obvious benefits of local capacity training and technology transfer, the arthropod initiative may benefit in diverse ways local collaborators and institutions associated with this long-term endeavor:

- Ecologists: access to results obtained over the SIGEO-CTFS network and related to arthropod **monitoring** and arthropod **food webs** centered on focal tree species.
- Taxonomists: varied entomological material of mostly tropical origin; access to barcoding information and opportunities to develop **global phylogenies**.
- Academic institutions: opportunities to develop **particular entomological projects** over the SIGEO-CTFS network; comparisons of temperate and tropical faunas; emulation of local entomological societies.
- Entomological societies: **collaborative project**, under strict scientific supervision provided by local academic institutions; opportunities for individual or joint collaboration at tropical plots; being part of an 'entomological network', which will expand.

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