

EARTHWATCH INSTITUTE FIELD REPORT

Project Title: Forest Caterpillars

Principal Investigator: Lee Dyer

Position/Affiliations: Professor, Tulane University

Research Sites and Local Management Status:

Napo, Ecuador, -0.583, -76.13, Biological Reserve, National Park
Sarapiquí, Costa Rica, 10.4, -82.0, Biological Reserve, National Park
Arizona, USA, 31.88, -109.2, Biological Reserve, National Forest

Scientific names of primary species being studied:

Lepidoptera, Hymenoptera, Diptera, Angiosperms, Nemata

Key Research Objectives:

- What affects diversity and abundance of caterpillars and parasitoids in natural forests and adjacent agriculture (banana and alfalfa)?
- What parasitoids might be good candidates for biological control in banana plantations and alfalfa fields?
- How do variation in precipitation and temperature affect levels of parasitism (and subsequently affect caterpillar densities)?

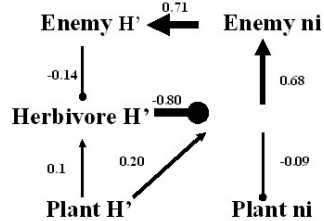
Date this report was completed: January 29 2006

Data Collection and Results

Diversity relationships

One objective of our Earthwatch caterpillar research was to determine the effects of plant-herbivore-predator interactions on biodiversity. We measured grassland plant and insect diversity at our Arizona site to document patterns of diversity at multiple trophic levels. The study sites included unmanaged pasture intermixed along riparian forest, and cattle grazed pasture with flood irrigation. We found that plant abundance and richness were higher on the grazed-irrigated pasture versus the unmanaged field. Structural equation models revealed strong effects of herbivore (including caterpillars) diversity on diversity of other trophic levels (mostly parasitoids). For the grazed fields, top-down forces were important, with enemy diversity depressing herbivore diversity, which in turn depressed plant diversity. For the unmanaged fields, bottom-up forces dominated, with plant diversity causing increased herbivore diversity, which in turn increased enemy diversity (Figure 1). For all fields, detritivore diversity was enhanced by overall arthropod diversity. Increasing productivity (i.e. adding fertilizer) caused increases in detritivore numbers, but lower diversity. These results support hypotheses from other empirical studies that changes in diversity of a single trophic level can cascade to effect diversity at other, nonadjacent trophic levels. Understanding such diversity relationships across ecosystems is necessary for directing management of these systems.

MANAGED



UNMANAGED

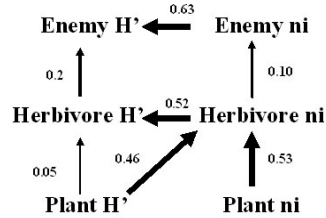


Figure 1. Path diagrams based on analyses of Earthwatch plot data, as well as experimental data from managed and unmanaged grasslands. Arrows indicate positive effects, lines with a circle-head indicate negative effects. Numbers next to effects are values of significant path coefficients and indicate the size of the effect. H' = arthropod diversity, ni = arthropod abundance.

Climatic unpredictability and parasitism of caterpillars: implications of global warming

Numerous Earthwatch teams quantified parasitism at our research sites in Louisiana, Ecuador, Costa Rica, and Arizona. Our most significant finding is relevant to the hypothesis insect outbreaks will increase in frequency and intensity with projected changes in global climate through direct effects of climate change on insect populations. While there is much concern about mean changes in global climate, the impact of climatic variability itself on species interactions has been little explored. We combined data from our 4 Earthwatch sites with 11 additional sites that covered a broad gradient of climatic variability and found a decrease in levels of parasitism as climatic variability increases (Figure 2). The dominant contribution to this pattern by relatively specialized parasitoid wasps suggests that climatic variability impairs the ability of parasitoids to track host populations. Given the important role of parasitoids in regulating insect herbivore populations in natural and managed systems, we predict an increase in the frequency and intensity of herbivore outbreaks through a disruption of enemy-herbivore dynamics as climates become more variable.

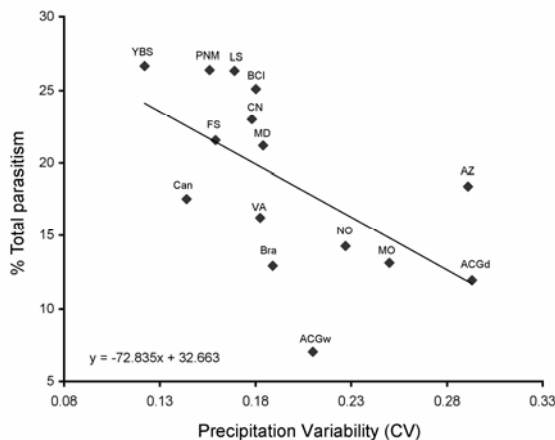


Figure 2. A linear regression of total parasitism levels of caterpillars from fifteen extensive rearing programs against year-to-year variability in precipitation (CV; $R^2 = 0.33$). Letter codes correspond to sites of rearing studies; AZ = Arizona, USA; ACGd = Guanacaste Conservation Area, Costa Rica, dry forest; ACGr = rain forest; LS = La Selva Biological Station, Costa Rica; YBS = Yanayacu Biological Station, Ecuador; NO = Southeast Louisiana, USA; Bra = Reserva Ecológica do IBGE, Brazil; BCI = Barro Colorado Island, Panama; PNM = Parque

Nacional Metropolitana, Panama; FS = Fort Sherman, Panama; Can = Southern Ontario, Canada; MD = Maryland, USA; MO = Southern Missouri, USA; VA = Virginia and West Virginia, USA.

Predicting caterpillar parasitism in agricultural systems

Leaf damage caused by Lepidoptera as they are responsible for the majority of the herbivory suffered by rainforest plants as well as many agricultural systems, including banana plantations. We used Earthwatch parasitism data to link ecological theory to the biological control of insect pests in banana plantations. Through our established predictive approach, ecological data on plant-caterpillar-parasitoid interactions from natural systems were used to formulate simple recommendations for biological control in banana plantations. The specific goals were (1) to determine the most effective parasitoid enemies for biological control of caterpillars in banana plantations and (2) to examine the impact of nematicides on enemy populations. To assess percent parasitism, we reared 1,121 caterpillars collected from six plantations managed under two nematicide regimens. Attack by parasitoids in the families Tachinidae (Diptera), Braconidae, Eulophidae, and Chalcididae (Hymenoptera) closely paralleled rates reported for species with similar characteristics at our Earthwatch site at La Selva, and statistical models predicted the relative importance of these parasitoids as sources of mortality. We found that tachinid flies were the most important source of early instar larval parasitism in banana plantations, and their importance increased with more intensive nematicide applications. The statistical models that we derived from data at La Selva were useful in predicting which parasitoids would be important in banana and which larval characteristics they would preferentially attack. We provided predictions for caterpillars that can occur in other banana plantations (Table 1), especially those that shift from insecticide use to biological control. This approach could be used in other managed ecosystems (e.g., near our sites in Ecuador and Arizona) where the identification of effective biological control agents is needed.

Caterpillar	Predicted parasitism ^a
<i>Acharia hyperocha</i> (Limacodidae)	Braconidae—70.0 (7.3)
	Eulophidae—53.3 (4.9)
	Tachinidae—19.7 (1.9)
<i>Hypercompe laeta</i> Walker (Arctiidae)	Tachinidae—19.7 (1.9)
	Braconidae—4.8 (1.2)
	Eulophidae—2.6 (0.7)
<i>Talides sinois</i> (Hesperiidae)	Tachinidae—25.7 (2.2)
	Braconidae—24.4 (2.4)
	Eulophidae—12.2 (1.8)

^a One individual host can support multiple parasitoid taxa (Gentry and Dyer 2002); thus, overall parasitism is not the sum of parasitism by families.

Table 1. Percent parasitism predictions (with SE in parentheses) for common species of Lepidoptera found in Costa Rican banana plantations based on logit models from Earthwatch data collected over the past 10 years. Parasitism levels over 30% are likely to result in successful biological control.

Significance/Benefits of Research

Diversity and natural history

Our most significant accomplishment is the compilation of natural history data related to approximately 2800 species of caterpillars, plants, and parasitoids. We share this natural

history information with locals and scientists alike (refer to the list of talks and publications), including talks in Spanish to Costa Rican and Ecuadorian students, naturalists, and local workers; the local talks have increased awareness and respect for insect diversity. Many of the naturalist guides at our research sites now point out caterpillars in their tourist walks and discuss the role they play in the forest. We also share these data with anyone who has internet access by publishing it on caterpillar web pages at www.caterpillars.org. The web pages are currently undergoing major improvements and should be a very useful tool for managing and studying biodiversity for many years to come. In addition, our basic research on diversity relationships between trophic levels will contribute to a growing understanding of how parasitoids and other natural enemies affect entire biotic communities.

Sustainable agriculture

Managers of banana plantations, alfalfa fields, and other agricultural systems who are attempting to control pests without using pesticides will benefit from increased knowledge of the parasitoid community. First, we discovered at least 12 new species of parasitoids (that are still being treated by taxonomists) in the families Braconidae and Tachinidae, all of which are potentially important biological control agents. Second, our modeling approach identified the most important biological control agents in banana plantations under different pesticide management, which allows plantation owners to manage for caterpillar pests without resorting to harmful insecticides.

Sustainable employment in the rainforest

Although it is not a direct benefit from the research, our Earthwatch project benefits the local communities by supporting the research stations and by continuing collaborations with local naturalists and scientists. Field stations generally benefit the local community by providing excellent employment opportunities that are not destructive to the forest and by boosting the local economy. At the Costa Rica site, we continue to provide long-term employment to local naturalists, Gerardo Vega and Humberto Garcia; at the Ecuador site, we have provided long-term employment to at least 3 full time field assistants. We plan to continue hiring as many local naturalists as possible, depending on continued funding from other sources.

Environmental education

Finally, our work has directly benefited the educational community because many volunteers have been school teachers and have incorporated ideas learned from this project into their classes. It has indirectly benefited the educational community because the research addresses basic theoretical questions in ecology. One of the most important issues to which our Earthwatch project has contributed is the idea of “trophic cascades.” Theory predicts that the effects of predators and parasitoids on plant biomass and diversity should not be great in complex systems such as rainforests, but we have demonstrated that the enemies of caterpillars significantly enhance plant biomass and diversity by killing caterpillars. This means that the consequences of tropical predator extinctions are more severe than previously thought, and predators of all sizes and all predatory guilds (i.e. including parasitoids) should be a major focus for conservation efforts.

Dissemination of Results (all publications below are available in pdf format at:
<http://www.tulane.edu/~ldyer/papers.htm>)

Peer reviewed articles and book chapters

Stireman III, J.O., L.A. Dyer, D.H. Janzen, M.S. Singer, J.T. Lill, R.J. Marquis, R.E. Ricklefs, G.L. Gentry, W. Hallwachs, P.D. Coley, J.A. Barone, H.F. Greeney, H. Connahs, P. Barbosa, H.C. Morais, and I.R. Diniz. 2005. Climatic unpredictability and caterpillar parasitism: implications of global warming. *Proceedings of the National Academy of Sciences* 102:17384-17387.

Dyer, L.A., Matlock, R.M., Cherzad, D., and R. O'Malley. 2005. Predicting successful biological control in banana plantations. *Environmental Entomology* 34:403-409.

Stireman, J.O. III, Dyer, L.A., and R.M. Matlock. 2005. Top-down forces in managed versus unmanaged habitats. Pages 303-323 in: Barbosa, P. and I. Castellanos (eds.). *Ecology of Predator-Prey Interactions*. Oxford University Press, Oxford.

Letourneau, D.K. and L.A. Dyer. 2005. Multi-trophic interactions and biodiversity: beetles, ants, caterpillars, and plants. Pages 366-385 in: Burslem, D.F.R.P.; Pinard, M.A.; Hartley, S.E. (eds.). *Biotic Interactions in the Tropics: Their Role in the Maintenance of Species Diversity*. Cambridge University Press, Cambridge, UK.

Irschick, D., Dyer, L.A., and T. Sherry. 2005. Phylogenetic methods for studying specialization. *Oikos* 110:404-408.

Presentations

Organization for Tropical Studies, Costa Rica, 2005

Yanayacu Biological Station, Ecuador, 2005

Indiana University, 2005

Ecological Society of America, Annual Meetings, 2005

University of California Davis, 2005

Bodega Marine Laboratory, 2005

Mesa State College, 2005

Rice University, 2005

University of Kentucky (Graduate Student Select Speaker), 2005

Louisiana State University, 2005