THE SCHOOL FOR FIELD STUDIES

Tropical Ecology of the Amazon
SFS 3831

Syllabus, Spring 2018

Laura Morales, Ph.D.
Resident Lecturer in Tropical Ecology

Office hours: by appointment

The School for Field Studies (SFS)
Center for Amazon Studies (CAS)
Loreto, Peru

Course Overview

Tropical regions are highly biodiverse and the Western Amazon region is one of *THE MOST* biodiverse places in the tropics. Ecology, the study of interactions of organisms with their environment, both its living and non-living components, can help us understand why and how this region harbors such a variety of life. In Tropical Ecology of the Amazon, we will be looking at the natural history and processes that created and sustain the region's biodiversity at multiple scales: species, community, ecosystem, and landscape.

The main goal of this course is for students to understand the processes that contribute to the diversity of life in the Western Amazon and gain insight into similar processes operating in tropical areas around the world. We will explore fundamental principles of ecology by studying a diverse set of ecosystems, habitats and species found here, including a variety of lowland tropical forest types and high-elevation forests at the headwaters of the Amazon River in the Andes Mountains.

Our exploration is grounded by three themes:

1. What is biodiversity? evolutionary origins, scales, and measurement
2. Why are the tropics so diverse? Interactions, ecosystem dynamics, succession
3. How does biodiversity respond to global change? Climate and land-use (past, present, future)

Using field methodology and guided by the scientific method, we will focus on learning tools that will allow students to measure, describe, and explain biodiversity and its dynamics. This course is closely linked to the *Conservation Science* course, where the focus will be more on threats to, monitoring of, and strategies for the conservation of biodiversity. It also will provide background information on the natural arena in which human use and extraction of Amazonian natural resources by global, national and local actors takes place (discussed in *Political Ecology of Developing Landscapes*).

The focus is on field-based and hands-on learning, so come prepared to get your feet wet and hands dirty.

Learning Objectives

In this course students should develop conceptual understandings and practical skills that afford them an appreciation of the diversity and complexity of the natural systems of the Amazon region. Specific learning objectives are the following:

1. Gain an understanding of ecological complexity of tropical ecosystems, evolutionary processes, and landscape patterns that underlie species diversity and co-existence.
2. Understand the richness of life forms and their interactions (herbivory, predation, parasitism, seed dispersal, pollination, co-evolution).
3. Describe the structure and composition of the major ecosystems in the Northwestern Amazon region.
4. Understand how a tropical forest functions: the processes of nutrient cycling, regeneration and response to disturbances, and the anatomical and physiological characteristics of tropical plants.
5. Employ the field research methods and analytical tools—both qualitative and quantitative—that are used in the study of ecology and biogeography.

Assessment

Assessment Item	Value (%)
Quizzes (3)	15
FLABs (2)	20
Communication & Collaboration in Science	
(1) Readings summary & oral presentation	5
(2) Peer-Review	5
FEX: Ecological Study	20
Final Exam	25
Participation	10
TOTAL	**100**

Assessment Descriptions

Quiz

Short quizzes will be administered throughout the semester to assess periodic comprehension of the course's material. Quiz questions will be synthetic and answers will be expected in essay form.

Field Lab 1: Measuring and Quantifying Biodiversity- Understory Plants

Students will systematically survey and collect understory plants along the trails of the CAS forest, and try to identify them to the lowest taxonomic unit. We will use this data to explore the different metrics used to quantify and compare biodiversity between different samples (species accumulation curves, diversity indices). Students will work in groups to generate this information for their samples and we will come together to compare the results of different groups. A short written assignment explaining the methods and results will be handed in by each group for feedback.

Field Lab 2: Vertical Zonation in the Forest Canopy

On a self-guided walk along the canopy walkway, students will make observations of canopy closure and light levels, and general vegetation structure. We will come together as a class to discuss our observations of any patterns they observed, hypotheses regarding any natural patterns and how we might test them. Each student will then pick one of the patterns and hypotheses brainstormed and write a small report on how we might use carefully planned observational surveys or manipulative experiments test on of the hypothesis discussed.

FEX: Measuring and Quantifying Biodiversity- Forest Trees & Forest Structure

We will survey tree diversity and forest structure at three different forest types (white-sand forest, secondary *terra firme* forest, and more mature *terra firme* forest) in order to compare and contrast them. Using several plots or transects at each site, we will register tree morphospecies and standard forest structure metrics (tree height, DBH, canopy cover) at each site. We will use standard statistical analyses (ANOVA and Chi-Square Tests) to compare and contrast the sites. Analyses will be done in groups, but students will turn in short individual reports using scientific article structure. A grading rubric will be provided separately.

Science Communication and Collaboration Assignments

Effective communication of findings and ideas, and collaboration among individual scientists are important for the advancement of science. Written research and review articles are one important tool for communication among scientists and learning to read them effectively is an important skill not only for understanding and eventually writing scientific papers. In addition to collaboration on research projects, scientific peers also frequently collaborate on writing by serving as peer-reviewers of manuscripts in progress or submitted to journals. You will practice how to effectively and efficiently read and convey information in research/review articles and provide constructive criticism

(1) Readings summary & Oral Presentation

Students will present a brief (1-2 paragraphs) written summary of one of the course readings and deliver an oral summary to the class before or during the class period correspondent to the reading. Detailed instructions will be given at the start of the course.

(2) FLAB Report Peer-review

Students will read and review a classmate's field exercise reports and provide feedback in the form of a "Letter to the Editor." Detailed instructions will be given at the time of the assignment.

Exam

The final exam is closed-book. You will be given time to study for the exam; a class period will be designated as review. You will be examined on what you have been exposed to in class (lectures, discussions, etc.) and in the field, and what you have been asked to read. The exams allow students to draw on multiple concepts and experiences, and to synthesize information.

Grading Scheme

A	95.00 – 100.00%	B+	86.00 – 89.99%	C+	76.00 – 79.99%	D	60.00-69.00%
A-	90.00 – 94.99%	B	83.00 – 85.99%	C	73.00 – 75.99%	F	0.00 – 59.99%
		B-	80.00 – 82.99%	C-	70.00 – 72.99%		

General Reminders

Readings – Most readings required and some are optional but reviewing them is strongly encouraged as they will enhance your understanding of the lecture and field lecture material, and serve as examples of how to write scientific papers. Readings are available as PDFs on the Student Drive or from internet hyperlinks. The reading list might be updated or changed during the course of the semester.

Plagiarism - Using the ideas and material of others without giving due credit, is cheating and will not be tolerated. A grade of zero will be assigned if anyone is caught cheating or aiding another person to cheat actively or passively (e.g., allowing someone to look at your exam). All assignments unless specifically stated should be individual pieces of work.

Deadlines - Deadlines for written and oral assignments are instated for several reasons: They are a part of working life to which students need to become accustomed and promote equity among students, and deadlines allow faculty time to review and return assignments before others are due. Assignments will be handed back to students after a one-week grading period. Late assignments will incur a 10% penalty for each day that they are late. No assignment will be accepted after three days.

Participation - Since we offer a program that is likely more intensive than you might be used to at your home institution, missing even one lecture can have a proportionally greater effect on your final grade simply because there is little room to make up for lost time. Participation in all components of the program is mandatory because your actions can significantly affect the experience you and your classmates have while at SFS. Therefore, it is important that you are prompt for all land and water based activities, bring the necessary equipment for field exercises and directed research, and simply get involved.

Course Content

Type: L-Lecture, **FL-** Field Lecture, **FEX-** Field Exercise, **FLAB-** Field Lab Exercise, **LAB-** Lab Exercise

Code (Type)	*Hrs*	*Lecture Title and Description*	*Reading*
TE1 (L)	**1.0**	**Introduction to Tropical Ecology: Course Overview** This lecture will introduce tropical ecology as an interdisciplinary field and set course expectations.	Week 1
TE2 (L)	**1.0**	**The Torrid Zone: Climate & Soils of the Tropics** What does "tropical" mean? This lecture will explore how terrestrial astronomy and how the interactions between air, water, and landmasses generates tropical ecosystems. It will also explore characteristics and distributions of soils in the tropics and how they create variability in the landscape.	Week 1 Optional: *Quesada et al. (2011)*
TE3 (L/FL)	**2.0**	**What is biodiversity?** This lecture and field lecture will review the different definitions of biological diversity ranging from genetic to landscape scales. We will also discuss the species concept and diversity indices in preparation for our field practices measuring biodiversity.	Week 1
TE4 (L/FL/D)	**2.0**	**The Western Amazon as a Biodiversity Hotspot** We will examine the biodiversity of tropical regions and the Western Amazon in a global context (latitudinal diversity gradient, biodiversity hotspot concept). A guided walk in the forest around our center will introduce students to some of this diversity and let them start honing their observation skills.	Week 1 *Gentry (1988)* Optional: *Hillebrand (2004)*
TE5 (GL/FL/LAB)	**2.0**	**Tropical Plant Families** We will be introduced to some of the most important tropical families and how to identify them using a tropical botanist's best tool-kit: sight, sound, smell and taste. We will also discuss how to make and use herbarium specimens. (Guest Instructor: Fredy Ramirez Arevalo, M.Sc.)	Week 2 *Cardoso et al. (2017)*
TE6 (FLAB1)	**3.0**	**Measuring Biodiversity** How can we measure biodiversity? We will review classic methods and indices used to quantify biodiversity and put them to practice with a field lab exploring the floristic diversity along the trails in our center.	Week 2 *Longino et al. (2002)* Optional:

Code (Type)	Hrs	Lecture Title and Description	Reading
		(Quiz 1)	Gotelli & Colwell (2001)
TE7 (L/FL/FEX)	**4.0**	**Tropical Forests: Types & Structure** We will discuss different classifications of forest and learn about the four major forest types of the lowland Amazon we will see during the course. We will also introduce ways of measuring and quantifying forest structure, with field practicums at upland forest (CAS Forest) and non-flooded white sand forest (Field Trip to Allpahuayo-Mishana). -Data collection at CAS & Allpahuay-Mishana	Week 2/3 *Adeney et al. (2016)* *Stropp et al. (2011)* Optional: *Myster (2016)*
TE8 (FLAB2)	**2.0**	**Into the Treetops** How does the forest environment change vertically and how to organisms use this structure? We will use a canopy walkway to explore the vertical structure of a mature rainforest and observe how light and temperature varies with height, and how organisms such as epiphytes and birds change along this gradient. (FLAB 1 DUE)	Week 3 *Madigosky & Vatnick (2000)* *Hietz & Briones (1998)*
TE9 (FEX)	**1.5**	**FEX Continued- Mature Forest Data Collection** (Sucusari/ExploNapo Forest)	Week 3
TE10 (FL/D)	**1.5**	**Into the "Jungle": Tropical Forest Succession** During this field lecture, we will examine the role of disturbance (human and natural) in tropical forests and the subsequent process of recovery and vegetation change, discussing our qualitative impressions of differences between the forests around ExploNapo, our home center, and abandoned chacras observed in the community of Sucusari.	Week 3 *Norden et al. (2017)*
TE11 (FL/D)	**2.0**	**Of Chemical & Other Warfare: Plant Defenses & Secondary Compounds** What do human plant uses have to do with insects? With a diversity of plants, comes a diversity of enemies. In this field lecture we will explore the diverse adaptations plants use to protect themselves against natural enemies and how these defenses have been exploited by humans and other animals. This will include a visit to a traditional medicinal garden and a discussion of a local healer's explanation of the variety of medicinal uses.	Week 3 *Agrawal and Konno (2009)*
TE12 (L/D)	**1.5**	**Why are the tropics so biodiverse?** We'll examine the different ideas for why the tropics house so many different species and the evidence for and against each hypothesis. (FLAB 2 Due)	Week 4 *Optional: Mittelbach et al. 2007*
TE13 (L/FLAB3/D)	**4.0**	**Birds of a Feather Don't Flock Together: Coexistence in Lowland Tropical Bird Communities** Mixed-species bird flocks are an enigmatic example of coexistence of multiple species that could be competing for resources. In this lecture and field lab, we will explore lowland bird communities and mechanisms for species coexistence. We will use mist-netting and early morning bird observations to gain	Week 4 *Sridhar et al. (2012)*

Code (Type)	Hrs	Lecture Title and Description	Reading
		familiarity with the local bird species and discuss the hypotheses for the existence of mixed-species flocks.	
TE14 (L/FL/D)	**2.0**	**Lungs, kidneys, or liver of the earth?: Nutrient Cycling** Tropical forests, and the Amazon basin in particular, has been popularly dubbed the " lungs of the earth." In this lecture we will examine nutrient cycling and discuss the role of tropical forests in global biogeochemical (C ,N H20) cycles. Locally, we'll examine the puzzling story of N-fixation in the tropics.	Week 4 *Espirito-Santo et al. (2014)* *Houlton et al. (2008)*
	2.0	**FEX Data Analysis Workshop**	Week 4
TE15 (L/FL)	**2.0**	**"Summer Every Day, Winter Every Night": Tropical Alpine & Montane Ecosystems** We will examine how vegetation communities respond to montane climate and vegetation. Students will be introduced to the highland tropics and variety of ecosystems found in the Eastern Andes-Amazon interface as we cross across a west-east moisture gradient from Cuzco to Wayqecha Biological Station (high elevation wetlands, puna grassland, tussock grassland, and elfin/cloud forest). Along stops along the way, we will also discuss the different adaptations tropical alpine plants have to deal with the unique climatic challenges of living high in the tropics.	Week 5 *Sklenár et al. (2016)*
TE16 **(**FL)	**2.0**	**Montane Forests & Climate Change** How will the tropical treeline and montane forest respond to climate change? Cloud forests occur where a condensation belt around mountains creates high-humidity conditions, but climate change may change this humid belt. We will visit a new and ambitious manipulative "fog exclusion" experiment at Wayqecha Biological Station that seeks to answer how plants and nutrient cycling might respond to climate change.	Week 5 *Nadkarni & Solano (2002)*
TE17 (FL/L)	**2.0**	**Forest Islands in a Grassy Sea: The *Polylepis* Dilemma** We will visit high-elevation forests dominated by unique *Polylepis* trees found at Abra Malaga. These are some of the forests growing at the highest elevations in the world and of high conservation concern. We will discuss the causes and consequences of their patchy spatial distribution, their role as bird habitat, and their regeneration ecology. Back in the classroom we will discuss the open questions regarding the history and future of the biological community they host and the challenges to their conservation. (Quiz 2)	Week 5 *Lloyd & Marsden (2011)*
TE18 (L/FL)	**2.0**	**A Tangled Web I: Tropical Trophic Dynamics** Tropical food and interaction webs can be particularly complex. We will review the major organismal interactions and take a walk into the center forest to examine of the most iconic of tropical interactions (ant-plant mutualisms). (FEX Draft Due for Peer Review)	Week 7 *Frederickson & Gordon (2007)*

Code (Type)	Hrs	Lecture Title and Description	Reading
TE19 (FL/D)	**2.0**	**A Tangled Web II: Butterfly Microcosm** We will visit a butterfly farm and learn about how butterflies are raised by the community of San Rafael. Students will observe the incredible variety of interactions occurring in this one small system and how one species can have different interactions with different organisms throughout its life.	Week 7
TE20 (L/FL)	**3.0**	**Top-down Forces: Animal-Plant Interactions** Animals play a key role in shaping tropical forests as herbivores, pollinators, seed predators and seed dispersers. We will focus on the role that frugivorous mammals and large birds play in maintaining plant diversity and examine the varied consequences of defaunation for forest composition and biomass. **(Peer-Reviews Due)**	Week 7 *Terborgh et al. (2001)* *Paine & Beck (2007)*
TE21 (L)	**2.0**	**A Fishy Tale: Fish Diversity in the Amazon Basin** South America has an incredible diversity of fish. We will examine why the role geologic history had in shaping fish diversity in the Amazon basin. In preparation for a visit to an ornamental fish exporter and fish censuses during our Pacaya-Samiria excursion, we will learn about some of the most common Amazonian fish families.	Week 8 *Albert et al. (2011)* Further optional: *Lundberg et al. 2010*
	2.0	**FEX Writing Workshop**	Week 8
TE22 (L/FL/ GL)	**2.0**	**Climate Change I: Forest Response & Consequences** There is great interest but great uncertainty on how Amazonian ecosystems will respond to climate change. The responses of biotic components, particularly trees and microbial communities could have important consequences for biogeochemical cycles. Long-term monitoring and observations of responses to extreme climate events (drought/flood) can offer a window into potential responses. We will visit a *Mauritia flexuosa* palm swamp at Quistococha to see a new Eddy Covariance Flux tower meant to monitor carbon and water fluxes from this neotropical peatland and discuss what we already know about uplanland tree response to drought events. **(Final FEX Due)** (Quiz 3)	Week 8 *Feldpausch et al. (2016)*
TE23 (GL/L?)	**1.5**	**Climate Change II: Wildlife Response to Drought in Pacaya-Samiria** The alteration of flooding cycles due to climate change may also have profound impacts on wildlife populations. We will discuss the implications of results from mid-term monitoring studies in Pacaya-Samiria examining wildlife responses to drought and the differences observed between animal groups.	Week 8/9 *Bodmer et al. (2014)* Optional: *Bodmer et al. (2017)*
TE24 (L/D/FLAB)	**4.0**	**"The Fish and the Forests": The Ecology of Fish and Trees in the Amazon Floodplain** The floodplain forests of the Amazon are the setting of an incredible story of interdependence between fish and trees. This lecture will explain how fish affect forest structure in flooded	Week 9 *Lucas (2008)*

Code (Type)	Hrs	Lecture Title and Description	Reading
		forest and how in turn the trees and the forest are an important seasonal resource that can affect river fish populations and diversity.	
TE25	**2.0**	**Exam Review**	Week 10
TE26	**2.0**	**Final Exam**	Week 10
	60.0	**TOTAL CONTACT HOURS**	

COURSE BIBLIOGRAPHY

Adeney, J.M, Christensen, N.L., Vincentini, A., and M. Cohn-Haft (2016) White-sand Ecosystems in Amazonia. Biotropica 48: 7-23.

Agrawal, A. and K. Konno (2009) Latex: A Model for Understanding Mechanisms, Ecology, and Evolution of Plant Defense Against Herbivory. Annual Review of Ecology, Evolution, and Systematics 40: 311-331.

Albert, J. S., Carvalho, T. P., Petry, P., Holder, M. A., Maxime, E. L., et al. (2011) Aquatic Biodiversity in the Amazon: Habitat Specialization and Geographic Isolation Promote Species Richness. Animals : An Open Access Journal from MDPI 1: 205–241.

Bodmer, R., Fang. T., Puertas, P.E., Antunez, M., Chota, K. and W.E. Bodmer (2014). Abstract *in:* Cambio climático y fauna silvestre en la Amazonía Peruana. Pp. 25-26.

Bodmer R., Fang, T., Antunez, M., Puertas, P., Chota, K., *et al.* (2017) Impact of recent climate fluctuations on biodiversity and people in flooded forests of the Peruvian Amazon *in:* The Lima Declaration on Biodiversity and Climate Change: Contributions from Science to Policy for Sustainable Development. CBD Technical Series No. 89. (eds. Rodriguez, L. and I. Anderson). Secretariat of the Convention on Biological Diversity, Montreal. pp. 81-90.

Cardoso, D., Sarkinen, T., Alexander, S., Amorim, A., Bittrich, V., *et al.* (2017) Amazon plant diversity revealed by a taxonomically verified species list. Proceedings of the National Academy of Sciences 40: 10695-10700.

Espirito-Santo, F.D.B., Gloor, M., Keller, M., Mahli, Y. *et al.* (2014) Size and frequency of natural forest disturbances and the Amazon forest carbon balance. Nature Communications 5:3434.

Feldpausch TR, Phillips OL, Brienen RJW, Gloor E, Lloyd J, *et al.*(2016) Amazon forest response to repeated droughts. Global Biogeochemical Cycles.

Frederickson, M.E. and D.M. Gordon (2007) The devil to pay: a cost of mutualism with *Myrmelachista schumanni* ants in 'devil's gardens' is increased herbivory on *Duroia hirsuta* trees. Proceedings of the Royal Society B 274: 1117-1123.

Gentry, A. (1988) Tree species richness of upper Amazonian forests. Proceedinga of the National Academy of Sciences 85: 156-159.

Gotelli, N.J. and R.K. Colwell (2001) Quantifying biodiversity: procedures and pitfalls in the measurement and comparison of species richness. Ecology Letters 4: 379-391.

Hietz, P. and O. Briones (1998) Correlation between water relations and within-canopy distribution of epiphytic ferns in a Mexican cloud forest. Oecologia 114:305-316.

Hillebrand, H. (2004) On the generality of the latitudinal diversity gradient. The American Naturalist 163:192-211.

Lloyd, H. and S.J. Marsden (2011) Between-patch bird movements within a High-Andean *Polylepis* woodland/matrix landscape: Implications for habitat restoration. Restoration Ecology 19:74-82.

Lucas, C.M. (2008) Within flood season variation in fruit consumption and seed dispersal by two characin fishes of the Amazon. Biotropica 40:581- 589.

Lundberg, J.G., Sabaj Perez, M.H., Dahdul, W.H. and O.A. Aguilera (2010) The Amazonian Neogene fish faunas *in*: Amazonia: Landscape and Species Evolution (eds. Hoorn C. and F. Wesselingh). Pp. 281-301.

Madigosky, S.R. and I. Vatnick (2000) Microclimatic characteristics of a primary tropical Amazonian rain forest, ACEER, Iquitos, Peru. Selbyana 21: 165-172.

Mittelbach, G.G., Schemske, D.W., Cornell, H.V., Allen, A.P., Brown, J.M., *et al.*(2007) Evolution and the latitudinal diversity gradient: speciation, extinction and biogeography. Ecology Letters 10: 315–331.

Myster, R.W. (2016) The Physical Structure of Forests in the Amazon Basin: a Review. Botanical Review 82: 407-427.

Nadkarnki, N.M. and R. Solano (2002) Potential effects of cliate change on canopy community in a tropical cloud forest: an experimental approach. Oecologia 131:580-586.

Norden, N., Boukili, V., Chao, A., Ma, K.H., *et al.* (2017) Opposing mechanisms affect taxonomic convergence between tree assemblages during tropical succession. Ecology Letters 20:1448-1458.

Paine, C.E.T. and H. Beck (2007) Seed predation by neotropical rain forest mammals increases diversity in seedling recruitment. Ecology 88: 3076-3078.

Sklenár, P., Kucevora, A., Macková, J. and K. Romoleroux (2016) Temperature microclimates of plants in a tropical alpine environment: How much does growth form matter? Arctic, Antarctic, and Alpine Research 48:61-78.

Sridhar, H., Srinavasan, U., Askins. R.A., Canales-Delgadillo, J.C., Chen, C., *et al.* (2012) Positive relationships between association strength and phenotypic similarity characterize the assembly of mixed-species bird flocks worldwide. The American Naturalist 180: 777-790.

Stropp, J., Van der Sleen, P., Assuncao, P.A. , da Silva, A.L. and H. Ter Steege (2011) Tree communities of white-sand and terra-firme forests of the upper Rio Negro. Acta Amazonica 41: 521-544.

Terborgh, J., Lopez, L., Nuñez P., Rhao, M., Shahabuddin, G., *et al.* (2001) Ecological Meltdown in Predator-Free Forest Fragments. Science 294: 1923- 1925.