Earthwatch 2018 Annual Field Report

CHEMICALLY MEDIATED TROPHIC INTERACTIONS, BIODIVERISTY AND CLIMATE CHANGE

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EARTHWATCH EXPEDITIONS,

30-JUNE TO 31-DECEMBER, 2018







18-Nov, 2019

Dear Volunteers,

What another great field season! Thanks to your hard work, we have thousands of new data points that will help us construct and learn from networks of plant-herbivore-enemy interactions. One of the most important networks created this year was the web of volunteers and researchers who can communicate the importance of insects and the threats they face as a result of global change. In 2018, we fielded 4 teams which allowed us to reach diverse audiences. In total, we had 34 volunteers helping us collect across the Americas from three of our research stations including Arizona, Costa Rica and Ecuador. We collected thousands of caterpillars in 2018, and the data from these caterpillars allows us to ask broader questions regarding tri-trophic interactions among plants, their Lepidopteran herbivores and associated parasitoids. Further, many of the parasitoids reared from the caterpillars we collected represent new interactions and species! Your help was both timely and important as these networks of interactions are being reshaped rapidly due to the loss of species and interactions. Long term data sets cataloguing insect interactions are rare, yet crucial for understanding the ecological consequences of global change. Our data allow us to quantify abundance, parasitism rates and interaction diversity across time, as well as providing insight into the ecological links between plant chemistry, herbivores and parasitoids. We are appreciative that you joined us to explore fascinating landscapes and the invertebrates that inhabit them.

We made some notable accomplishments in 2018. Our Arizona data set reached 10,000 entries which indicates over 10,000 caterpillars have been collected by Earthwatch volunteers in Southeast Arizona. For those of you who joined us for the Arizona, Costa Rica or Ecuador teams, we reared over 150 parasitoids that helped us evaluate trends in parasitism across our temperate and tropical sites. We have focused much of our research efforts to understanding insect declines and hope that our research will help the public understand the ecological consequences of extreme weather events in order to encourage climate-minded policy and management practices.

The report to follow details results from publications made possible by the hours you spent collecting and photographing caterpillars, cleaning out their frass and feeding them fresh host plant, and the hours scanning leaves for leaf area measurements. To put this in perspective, you contributed to over 3,000 person-hours of work in one year. We hope you enjoyed your time on our project and working together toward a common goal. We are fortunate to get to work with so many people of different backgrounds and are continually impressed by the high quality data that comes from such a collaborative effort. We hope the few weeks or days you spent with us encouraged you to zoom closer to the less explored world of insects, and appreciate all of earth's biodiversity. Those small connections have the potential to make substantive impacts when communicated to citizens who have the power to vote and impact the choices of future generations.

Our best regards, Danielle Salcido Lee Dyer

Danielle Salcido and Lee Dyer

SUMMARY

As a collaborative group of 4 Earthwatch teams, we collected over 7,577 caterpillars at 3 sites (Arizona, Costa Rica, Ecuador), reared out over 654 parasitic flies and wasps, discovered new phytochemicals, discovered dozens of novel interactions, and published over 10 papers in 2018 using years of accumulated Earthwatch data. Earthwatch teams that fielded in 2018 were instrumental in the collection of parasitoid data that will enable us to examine the topic of insect declines across our temperate and tropical sites. Further, we made progress documenting interaction phytochemical, and species diversity.

GOALS, OBJECTIVES, AND RESULTS

Objective 1: Determine how climate change and other global change parameters affect biodiversity.

We continue to make progress towards our long-term goals of determining effects of hurricanes, climatic variation, and other large scale disturbances on interaction diversity through our modeling approach and through empirical data (Scherrer *et al.* 2016). Our models, including analytical, simulation, and statistical approaches are being parameterized using all of the Earthwatch data from all of our sites (e.g., see Dyer & Forister 2016). To enhance these models, it is important we address questions that are seemingly unrelated to the climate-change-biodiversity crisis: *What are the consequences of changes in plant chemistry across climatic (elevation and precipitation) gradients? How do caterpillars and parasitoids respond? How does tri-trophic network structure change? What are the consequences for biodiversity and ecosystem management?* In 2018, we used 19 years of Earthwatch data in Costa Rica and Ecuador to address these questions and 10 papers (published in 2018) in top journals about these topics (e.g., Dyer et al. 2018a,b,c,d, Giron *et al*. 2018, Lepesqueur *et al.* 2018, Richards *et al.*2018, Slinn *et al.* 2018, Pardikes *et al.* 2018).

Specifically, we made significant progress toward developing state-of-the-art methods in understanding chemically mediated tri-trophic interactions. The synthesis of these ideas lead to two publications, one an invited publication for Nature Reviews Chemistry, that mapped out modern approaches for studying chemically-mediated plant-insect interactions (Dyer et al. 2018a, Richards et al. 2018). In Richards *et al. (*2018), we developed novel methods using network approaches to characterize chemical mixtures. The leaf samples of multiple Piper species (collected by Earthwatch volunteers) were sent to UNR for processing and bioassays. Extracts were prepared and characterized using a novel technique- network modules (Fig.1A) and then applied to various biological assays to determine anti-fungal, anti-bacterial and growth inhibitory effects of inferred chemical compounds (Fig.1B). These findings have important implications for natural products chemistry and potential for discovering compounds with biological activity with applications in drugs, pesticides and herbicides. Another really cool finding revealed from samples of *Piper kelleyi* leaves collected by volunteers was the relationship between plant chemistry and plant developmental stage. Seedlings, saplings and young leaves had very unique chemical profiles at these different stages (Fig. 2). One can imagine that as climate change impacts the development time of plants and insects, delayed or accelerated plant growth may introduce herbivores to compounds they may otherwise not have encountered with consequences for their interactions with natural enemies. For example, phytochemical diversity has already been shown by our lab to make herbivores more vulnerable to parasitoids (Richards et al. 2015, Richards et al. 2016, Slinn et al. 2018) or pathogens (Smilanich et al. 2017). Taken together, these published results are another example demonstrating the complex mechanisms by which climate change can alter biodiversity and provides an impetus to document the vast unknown biodiversity and associated natural history on earth (see also Dyer et al. 2018c, Smilanich et al. 2017, Giron et al. 2018). We continue to model the importance of interaction diversity as buffers to climate change and disruptive effects of losing biodiversity and we plan to continue the research over the coming decades.

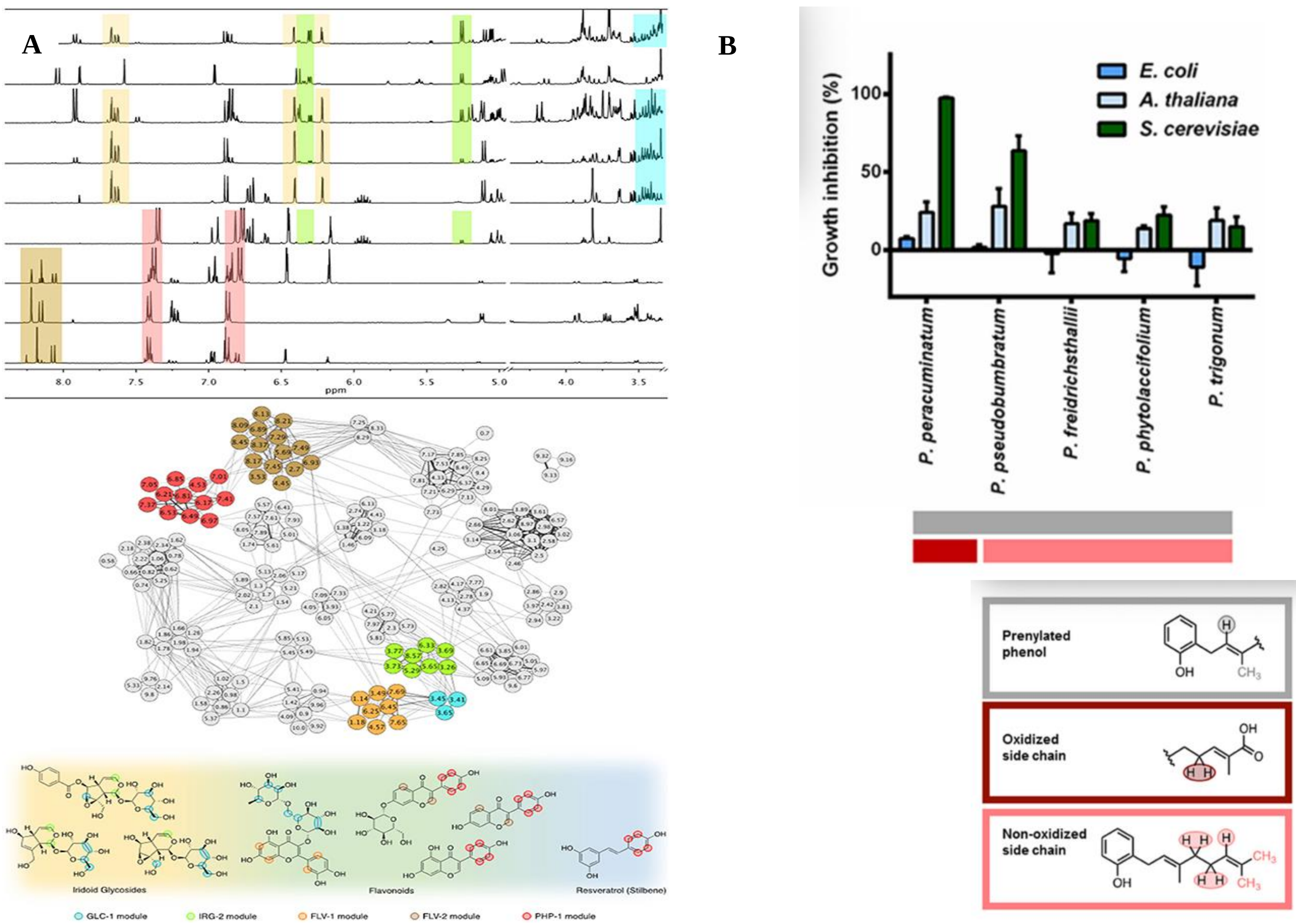

Figure 1. (A) A schematic that shows how data from H-NMR spectra can be represented as network modules. Modules represent characteristic features of chemical compounds. (B) Shows results of bioassays that test the effect of extracts from 5 *Piper* plants (*P. peracuminatum, P. pseudobumbratum, P. freidrichsthalli, P. phytolaccifollium, P. trigonum*) on growth of a bacteria (Escherichia coli), a plant (Arabidosis thaliana) and a fungus (Saxxharomyces cerecisae). All species contain prenylated phenol, but only *P. peracuminatum* has the oxidized side chain that is responsible for its stronger anti-fungal properties compared to the other species with a non-oxidized side chain. Taken from Richards et al. 2018. Our Earthwatch teams in Costa Rica and Ecuador collected and prepared leaf samples for this project.

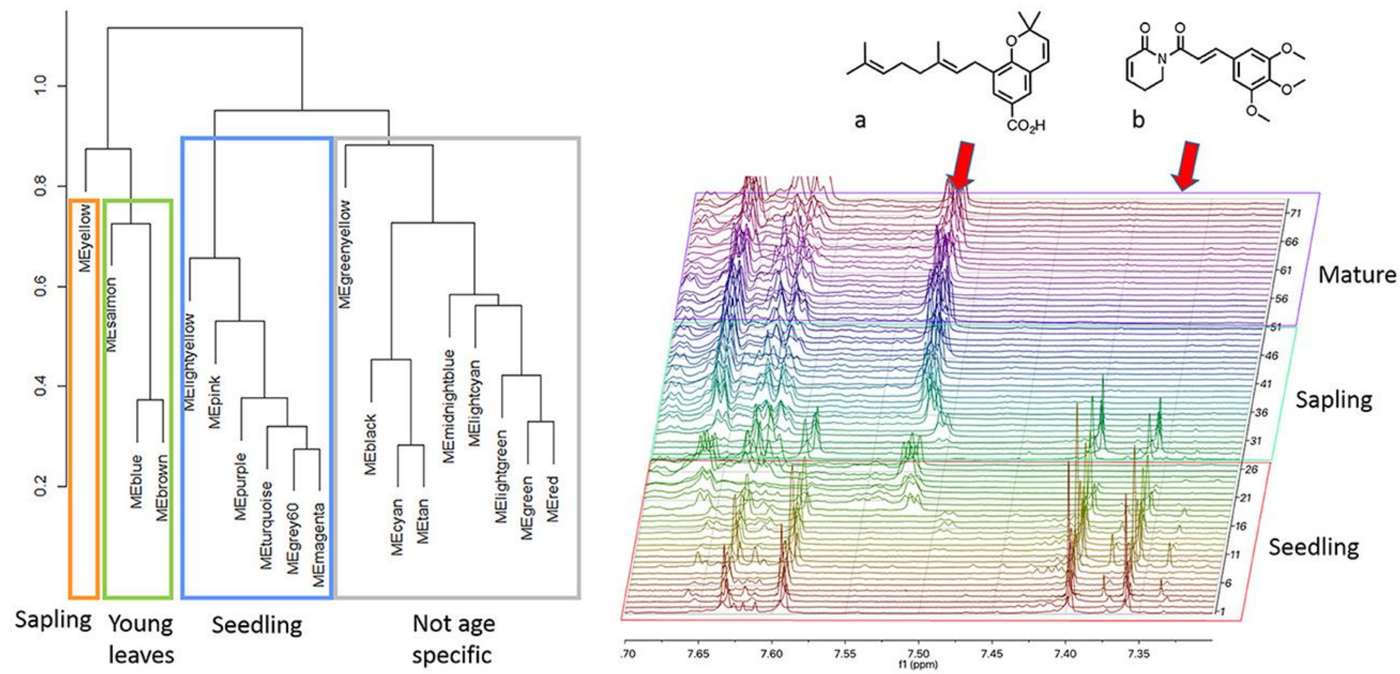

Figure 2. Phylogeny of the unique chemical features (branches of the cladogram) for various growth stages of a plant (ie. sapling, young leaves, seedling, other) and the associated H-NMR spectra from which chemical structure can be inferred.

Objective 2: Determine how hurricanes and variation in climate affect levels of parasitism and caterpillar densities.

Models of climate change have predicted greater frequency and duration of droughts and floods and a widespread increase in the frequency of extreme weather events (e.g., Rahmstorf and Coumou 2011). Such increased unpredictability and variability in regional climates will likely impact all aspects of biodiversity, including interactions between plants, caterpillars, and their natural enemies. In 2017, we began exploring long-term trends in parasitism rates at our tropical site in Costa Rica and found evidence declines in parasitism (Fig. 3A), but noticed that their host abundances are also declining (Fig. 3B). In 2018, we continued focused collection of parasitoids in Costa Rica and Ecuador with the help of Earthwatch volunteers. Costa Rica continues to experience an increased frequency of flooding events and prior investigations exploring the relationship between precipitation variability and parasitism (Stireman et al. 2005) indicate that greater precipitation variability is strongly correlated with parasitism frequency and has disproportionate effects on specialized parasitoids. Over 33-years of local precipitation data at La Selva corroborate observations of the increased frequency of extreme precipitation events and for lowland tropical forests like La Selva which is surrounded by two large rivers, the Rio Sarapiqui and Rio Puerto Viejo, flooding events impact population sizes and cycles of caterpillars and associated parasitoids through its direct and indirect effects on survival rates, development time and the availability and quality of host plants. Flooding likely has disproportionate effects on understory species, particularly those that pupate in the soil or feed externally on understory shrubs as larvae. Our most recent assessment, has indicated that declines in diversity are widespread among multiple insect trophic levels. (Fig. 4). We have continued to pursue causal effects of these declines including changes in climate parameters. Thanks to the support of many former Earthwatch volunteers, we successfully funded a crowd-funding campaign in early 2012 to support our two field technicians, Beto Garcia and Wilmer Simbaña, to collect a year of continuous parasitism data.

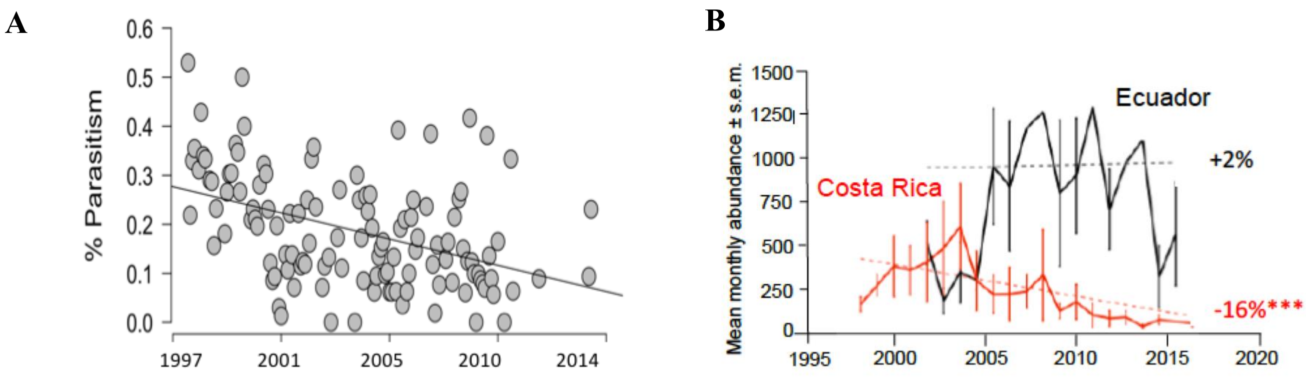

Figure 3. (A) Parasitism rates of Lepidopteran herbivores collected in La Selva, Costa Rica using 16- years of data. Each data point represents parasitism frequency for each continuous month from January 1997 to January 2015. Parasitism frequency is calculated as the ratio of parasitized caterpillars to sum of parasitized individuals and those that emerged as adults. Earthwatch teams in Costa Rica, Ecuador, Arizona, and the Sierra Nevada will continue to collect caterpillar and rear for parasitoids to understand temporal and latitudinal trends in parasitism rates and how these effect species network structure. **(B)** Mean monthly caterpillar abundance using 20-years of volunteer collected data from Costa Rica and Ecuador. Caterpillar abundance collected from La Selva Biological Research Station, Costa Rica has exhibited steady and dramatic declines, however this pattern is not evident for our other long-term tropical site, Ecuador. This provides support for the negative impact of extreme weather events and land use practices on herbivore populations. The disparate patterns among the two tropical Protected Areas are likely an artefact of the synergistic effects of extreme weather events and land use practices. Unlike Ecuador, the forests of La Selva are bounded by agriculture that applies the largest quantities of pesticide per hectare in the world and has experienced increased frequency of flooding events.

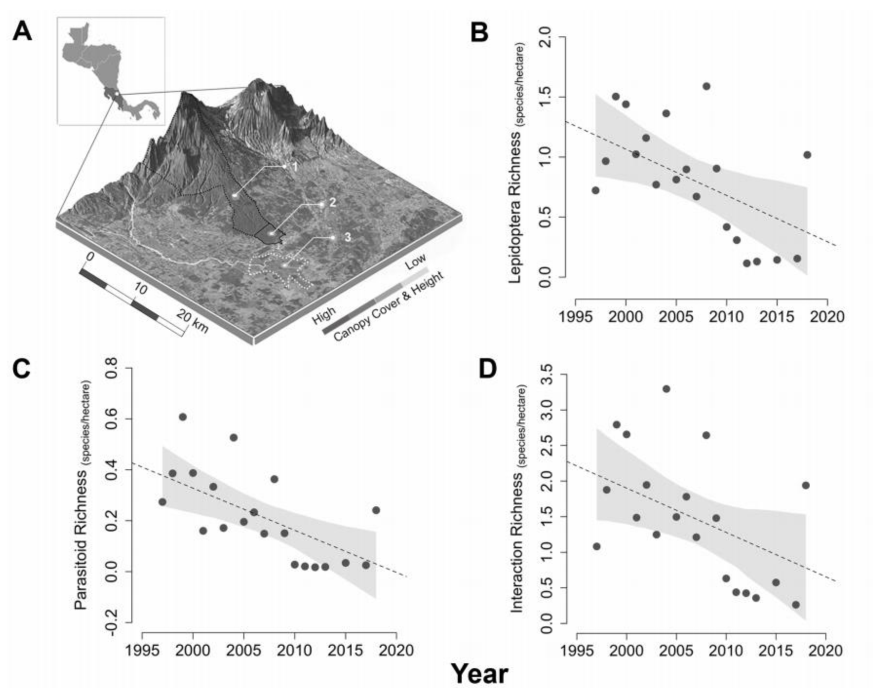

Figure 4. Insect declines across 22-years of sampling at La Selva Biological Research Station. Braulio Carillo National Forest (A.l) and surrounding areas, including La Selva (A.2), which has experienced declines in caterpillar (B), associated parasitoid diversity (C) and interaction diversity (D) over the past 22 years (1997-2018).

Objective 3: Specialization, trophic interactions, and biodiversity

The diet breadth or host range of insects has been a focal point for understanding current levels of biodiversity, which are increasingly threatened by global change. Estimates of species richness (counts of the numbers of species in an area) that are published for the most diverse forests on earth are only crude approximations, and the methods for estimating biodiversity rely on poor natural history data and untested assumptions about herbivore specialization (Basset et al. 2012). For years our Earthwatch data have facilitated investigation of specialization and co-diversification across multiple trophic levels (Forister et al. 2015) , a long-standing challenge in biodiversity research and evolutionary theory. In 2018 we made excellent progress towards documenting specialization across climatic and latitudinal gradients, and we published a half dozen papers about this topic in 2018 (Giron et al. 2018, Dyer 2018b, Pardikes et al. 2018, Slinn et al. 2018). In these papers we report strong pattern of relationships between climate, plant chemistry, and specialization. Along with these published results, we developed theoretical frameworks and future approaches to studying multi-trophic plant -insect interactions (Dyer et al. 2018a, Dyer 2018b, Giron et al. 2018, Richards et al. 2018). For example, Dyer *et al.* 2018d showed that measures of diet breadth specialization, interaction diversity and connectance are scale dependent (Fig. 5). Many studies in ecology do not give consideration of biologically relevant scales (Dyer et al. 2015) in calculating these measures and this studies showed that at smaller more biologically relevant scales (plot-level data that Earthwatch volunteers help gather data from), a latitudinal gradient in diet breadth specialization emerges. This result adds valuable simulation-based data to our understanding of the latitudinal gradient of species interactions.

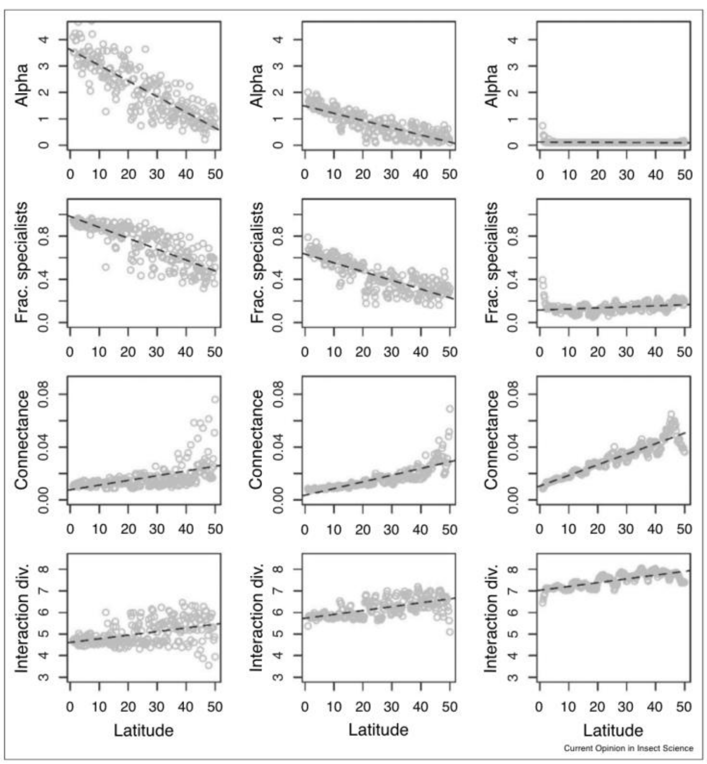

Figure 5. Changes in network parameters across a latitudinal gradient for different scales of data. Column1 represents plot-level data, column 2 are results for a larger scale (3 plots combined) and column 3 largest scale (11 plots combined). Network parameters include measures of diet breadth specialization (alpha & fraction of specialists), connectance and interaction diversity.

Objective 4: Discovery and descriptions of new species and new life histories

As we have reported in past years, another significant accomplishment for 2018 came in the form of new species and new chemistry discoveries. Most notably, we have continued to make progress developing pioneering methods to describe and analyze phytochemical compounds (Richards et al. 2018). These methods have helped us to further characterize the temperate and tropical model genus, *Juniperus* and *Piper*, respectively. We have reported in many other papers that plant chemistry changes with increases in temperature and CO_2 (Dyer et al. 2013). Chemical compounds produced by plants are not only responsible for the plants' unique flavors, aromas, and colors, but also possible deterrent or toxic properties and resistance to herbivores (e.g., Hansen et al. 2016).

Also similar to previous years, in 2018, we attempted to improve our sister sites to caterpillars.org – most notably the site created in collaboration with the Encyclopedia of Life (EOL). The URL for the site is: http://caterpillars.lifedesks.org/ . Both of these websites are in serious need of updates, and we plan to completely revamp them in the next two years, with the help of volunteers. One success toward this goal was recruiting the help of former Earthwatch volunteer, Julie Elliot. Julie has fielded 5 Caterpillar and Climate Change expeditions and has continued work with our team to curate and update caterpillars.org. In addition to updates to the life history data and images newly available on the web, we published several new life history descriptions for our focal taxa, many of which are the first biological information known for particular genera. We continue to rear out new species from the project at a rapid rate and we continue to publish species descriptions for as many of these as possible. At the Arizona site volunteers contributed to the Western North America caterpillar guide, the sequel to Dave Wagner's Eastern Caterpillars book. Finally, we were awarded a grant from the National Science Foundation (NSF) to integrate images of all our adult specimens with all other museums in North America – this effort is called "LepNet" and is summarized in Seltmann et al. (2017). In addition, genitalia dissections of reared specimens of what was believed to be a single species of Eois are revealing stunning diversity. Graduate student Lydia Doan is currently working on genitalia dissections (eg. Fig. 6) to uncover new species and drivers of that speciation.

A

B

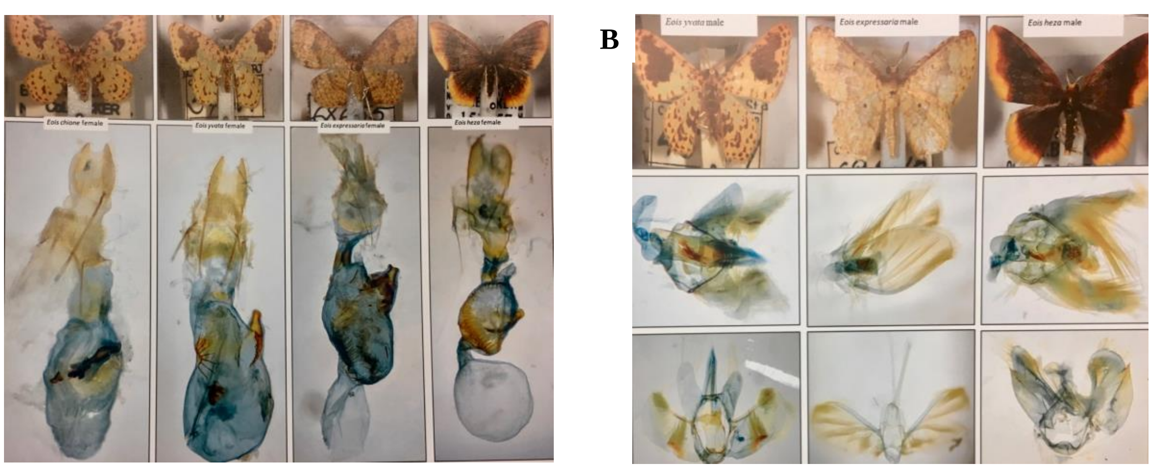

Figure 6. Images of male (A) and female (B) adults and genitalia dissections for various *Eois* species. Morphological features of genitalia are useful for species designations and often reveal new species. Earthwatch volunteers have contributed to the collection of thousands of *Eois* samples. At the Ecuador site in 2018, volunteers exhaustively searched *Piper lancifolium* for *Eois olivacia*. Lydia Doan, a graduate student at UNR has been dissecting and preparing genitalia dissections from these samples for the past year to describe and understand the diversification of this group.

PROJECT IMPACTS

Report contributions in the categories below for the past fielding year.

1. Increasing Scientific Knowledge

a) Total citizen science research hours

Eight hours per day, across 43 volunteer days, amounts to 344 hours for the 4 teams (43 volunteers). Approximately half the time was spent collecting data and the other half processing data. This is almost 14,792 person-hours of volunteer time.

For the following items, provide full references for publications and material resulting from or supported by your Earthwatch project, indicate the status of the publication (in press, published, etc.) and whether Earthwatch was acknowledged. Include papers/material from all staff, whether or not the PI is a co-author.

b) Peer-reviewed publications

Dyer, L.A., Philbin, C.S., Ochsenrider, K.M., Richards, L.A., Massad, T.J., Smilanich, A.M., Forister, M.L., Parchman, T.L., Galland, L.M., Hurtado, P.J., Espeset, A.E., Dodson, C.D., and C. Jeffrey. 2018a. Modern approaches to study plant–insect interactions in chemical ecology. Nature Reviews Chemistry 2:50–64. 117.

Dyer, L.A. 2018b. Book Review: The Phytochemical Landscape: Linking Trophic Interactions and Nutrient Dynamics. The Quarterly Review of Biology 93:169-170c

Dyer, L.A. 2018c. Multidimensional diversity associated with plants: a view from a plant– insect interaction ecologist. American Journal of Botany 105: 1–4. 120.

Dyer, L.A. and M.L. Forister. 2018d. Challenges and advances in the study of latitudinal gradients in multitrophic interactions, with a focus on consumer specialization. Current Opinion in Insect Science.

Giron D., Dubreuil G., Bennet A., Dedeine F., Dicke M., Dyer L., Erb M., Harris M.O., Huguet E., Kaloshian I., Kawakita A., Lopez -Vaamonde C., Palmer T.M., Petanidou T., Poulsen. M., Sallé A., Simon J.C., Terblanche J.S., Thiéry D., Whiteman N., Woods H.A., ZchoriFein E., and S. Pincebourde. 2018. Promises and challenges in insect–plant–microbe interactions. Entomologia Experimentalis et Applicata 166: 319-343.

Lepesqueur, C., S. Scherrer, M.C. Vieira, M. Almeida-Neto, D.M. Salcido, L.A. Dyer, I. Rezende Diniz 2018. Changing interactions among persistent species as the major driver of seasonal turnover in plant-caterpillar interactions. Plos ONE 13(9): e0203164.

Pardikes, N.A., W. Lumpkin, P.J. Hurtado, and L.A. Dyer. 2018. Simulated tri-trophic networks reveal complex relationships between species diversity and interaction diversity. Plos ONE 13(3):e0193822. https://doi.org/10.1371/journal.pone.0193822.

Richards, L.A., Oliveira, C. Dyer, L.A., Rumbaugh, A., Urbano-Munoz, F., Wallace, I.S., Dodson, C.D., and C. Jeffrey. 2018. Shedding light on chemically mediated tri-trophic interactions: A 1 H-NMR network approach to identify compound structural features and associated biological activity. Frontiers in Plant Science https://doi.org/10.3389/fpls.2018.01155.

Slinn H.L., Richards L.A., Dyer L.A., Hurtado P., Smilanich A.M. 2018. Across multiple species, Phytochemical diversity and herbivore diet breadth have cascading effects on herbivore immunity and parasitism in a tropical model system. Frontiers in Plant Science 9:656 doi: 10.3389/fpls.2018.00656. 116.

Smilanich, A.M., Langus, T.C., Doan, L., Dyer, L.A., Harrison, J.G., Hsueh, J. and Teglas, M.B., 2017. Host plant associated enhancement of immunity and survival in virus infected caterpillars. Journal of invertebrate pathology 151:102-112.

c) Presentations:

Plenary/Invited Talks

Dyer, L., Seminar Series, Academic, Seminar, "A rambling examination of the phytochemical landscape: Testing hypotheses from Darwin and Wallace, Ehrlich and Raven, HSS, and Lora Richards.", Invited, Michigan State University. (October 29, 2018).

Dyer, L., Seminar Series, Academic, Seminar, "Darwin's Tangled Bank: A View from Chemical Ecology.", Invited, University of Sao Paulo. (May 28, 2018).

Conference Oral Presentations

(partial, representative list)

Dyer, L., Salcido, D., Annual Meeting of the Ecological Society of America, Academic, Conference, "Responses of trophic interactions to stress at different spatial and temporal scales", Invited, Ecological Society of America. (November 14, 2018).

Salcido, D., Dyer, L., Annual Meeting of the Entomological Society of America, Academic, Conference, "Extreme weather events and disappearance of rare lepidopteran species in a tropical plant-caterpillar-parasitoid community.", Invited, Entomological Society of America. (November 14, 2018).

Kay, E., Dyer, L., Annual Meeting of the Entomological Society of America, Academic, Conference, "Phytochemical diversity in industrial hemp: Synergies in defense against an array of natural enemies", Invited, Entomological Society of America. (November 14, 2018).

Philbin, C., Dyer, L., Annual Meeting of the Ecological Society of America, Academic, Conference, "Partitioning the phytochemical landscape.", Accepted, Ecological Society of America. (August 9, 2018).

Slinn, H., Dyer, L., Annual Meeting of the Ecological Society of America, Academic, Conference, "Phytochemical diversity and herbivore diet breadth have cascading effects on herbivore immunity and parasitism", Accepted, Ecological Society of America. (August 9, 2018).

Richards, L., Dyer, L., Glassmire, A., Annual Meeting of the Ecological Society of America, Academic, Conference, "The role of phytochemical diversity on multi-trophic interactions", Invited, Ecological Society of America. (August 8, 2018).

Muchoney ND, Bowers MD, Carper AL, Teglas MB, Smilanich AM. Dec. 2018. Impacts of novel host plants on Nymphalid butterflies: The role of host plant chemistry in modulating herbivore protection against a viral pathogen. Oral presentation: Launch Symposium for the Hitchcock Center for Chemical Ecology. Reno, NV.

Muchoney ND, Bowers MD, Carper AL, Smilanich AM. Nov. 2018. Use of an introduced host plant provides protection against viral infection in a native insect herbivore, Anartia jatrophae. Oral presentation: Joint Annual Meeting of the Entomological Societies of America, Canada, and British Columbia. Vancouver, Canada.

Smilanich, A.M., *Mo, C., Bowers, D. 2018. "Effects of a densovirus on immunity, oviposition, and fecundity", Entomological Society of America, Vancouver B.C.

Poster Presentations

Muchoney ND, Bowers MD, Mason PA, Carper AL, Teglas MB, Smilanich AM. Aug. 2018. Variation in immune performance and interactions with a viral pathogen in a North American herbivore using native and novel host plants. Poster presentation: II Joint Congress on Evolutionary Biology. Montpellier, France.

Salcido, D. (2018): Extreme Precipitation Events and Increases in Temperature Parallel Declines in Ecosystem Function in a Tropical Plant-Caterpillar Parasitoid Community. Poster session at the Entomological Society of America Conference, Vancouver, Canada.

2. Outreach and Mentoring

a) Graduate students

List graduate students doing thesis work on the project and include student CVs and their research proposal on file with the university as an attachment when you submit your annual report

Student Name	Graduate Degree	Project Title	Anticipated Year of Completion
Jane Dell	PhD	Untangling patterns of diversity in a fire forest: Spatiotemporal influence and interactions.	2018
Will Lumpkin	PhD	Diversity cascades and effective biological control.	2020
Danielle Salcido	PhD	Global change, citizen science, and effective outreach for all ages.	2021
Heather Slinn	PhD	Tritrophic interactions mediated by chemistry and fungal endophytes.	2019
Santiago Villamarin	PhD	The value of scientific collections: Examining patterns of change in diversity and structure of Lepidoptera.	2022
Chanchanook Sudta	PhD	Tropical tritrophic interactions and the ecology of specialization.	2023
Ericka Kay	PhD	Chemical ecology of economically important plants.	2022
Tara Langus	PhD	Linking pollinator and consumer networks via secondary metabolites: implications for pollinator disease and conservation.	2025

b) Community outreach

Provide details on how you have supported the development of environmental leaders in the community in which you work.

Name of school, organization, or group	Education level	Participants local or non-local	Estimated number of participants	Details on contributions/ activities
Nevada Bugs and Butterflies	**All levels**	**local**	50	**Worked with Earthwatch volunteers and uses Earthwatch data as part of general outreach.**
Daugherty Summer Science Exploration	**K-9**	**local**	10	**Worked with Earthwatch volunteers in the field.**
UNR Museum	**All levels**	**local**	50	**Earthwatch volunteers assisted with National Pollinator Week activities.**
NevadaTeach	**Undergraduate**	**local**	2	**Prospective high school science teachers volunteer in our lab to diversify laboratory experience and expose prospective local Washoe County teachers to UNR research.**

3. Partnerships

List your current active professional partnerships that contribute to your project and indicate the type of support these partners provide

Partner	Support Type(s)[1]	Years of Association (e.g. 2006-present)
Serra Bonita Reserve, Bahia, Brazil	partners in research, access to specimens, accepts voucher specimens in museum, contributes to conservation goals	**2014-present**
Fundo Genova, Chanchamayo, Peru	partners in research, access to specimens, contributes to conservation goals	**2013-present**
Organization for Tropical Studies	partners in research, access to specimens, contributes to conservation goals	**1991-present**
Smithsonian National Museum of Natural History (UNMSM)	partners in research, provides space and access to specimens, accepts voucher specimens in museum	**2004-present**
American Museum of Natural History	partners in research, provides space and access to specimens, accepts voucher specimens in museum	**2004-present**
Museo de Historia Natural, Lima, Peru	partners in research, provides space and access to specimens, accepts voucher specimens in museum	**2012-present**
Museo Ecuatoriano de Ciencias Naturales (MECN), now the Institute for Biodiversity	partners in research, provides space and access to specimens, accepts voucher specimens in museum	**2002-present**
University of Nevada Natural History Museum	partners in research, provides space and access to specimens, accepts voucher specimens in museum	**2015-present**
University of Brasilia	partners in research, access to specimens	**2008-present**

FAPESP Sao Paulo Research Foundation	**provides additional funding and contributes to outreach goals**	**2014-present**
Conselho Nacional de Desenvolvimento Científico e Tecnológico	**provides additional funding and contributes to outreach and training goals (Science without Borders)**	**2013-present**
Yanayacu Biological Station	**partners in research, contributes to conservation and outreach goals**	**2001-present**
Southern Research Station, USFS	**provide funding for the Florida site, collaborate, contribute to management plans for Eglin**	**2012-present**
INBIO, Costa Rica	**partners in research, provides space and access to specimens, accepts voucher specimens in museum**	**1991-present**

1. Support type options: funding, data, logistics, permits, technical support, collaboration, academic support, cultural support, other (define)

4. Contributions to management plans or policies

List the management plans/policies to which your project contributed this year

Nothing to report yet. Our new efforts in Ecuador should soon yield enhancements to management policies.

Plan/Policy Name	Type[2]	Level of Impact[3]	New or Existing?	Primary goal of plan/policy[4]	Stage of plan/policy[5]	Description of Contribution

2. Type options: agenda, convention, development plan, management plan, policy, or other (define)
3. Level of impact options: local, regional, national, international
4. Primary goal options: cultural conservation, land conservation, species conservation, natural resource conservation, other (define)
5. Stage of plan/policy options: proposed, in progress, adopted, other (define)

5. Conserving natural and sociocultural capital - *Nothing to report yet. Our new efforts on pollinators should soon yield enhancements to conservation.*

Conservation of taxa

i. ***List any focal study species that you did not list in your most recent proposal***

Species	Common name	IUCN Red List category	Local/regional conservation status	Local/regional conservation status source

ii. *In the past year, has your project helped conserve or restore populations of species of conservation significance? If so, please describe below.*

Species	IUCN Red List category	Local/regional conservation status	Local/regional conservation status source	Description of contribution	Resulting effect[6]

6. Resulting effect options: decreased competition, improved habitat for species, range increased, population increase, improved population structure, increased breeding success, maintained/enhanced genetic diversity, other

Conservation of ecosystems

In the past year, has your project helped conserve or restore habitats? If so, please describe below.

Habitat type	Habitat significance[7]	Description of contribution	Resulting effect[8]
Cloud forest	Extremely high levels of diversity and endemism.	Providing an economic incentive for managing lands for biodiversity by supporting the only research station in the area and providing long-term employment to local citizens.	Yanayacu Biological Station and surrounding lands are still protected from logging, grazing, and development.

7. Habitat significance options: nursery, breeding ground, feeding site, corridor, migration path, refuge, winter range, summer range, spring range, fall range or other (define)

8. Resulting effect options: extent maintained, condition achieved, restored, expanded, improved connectivity or resilience

Ecosystem services

*Indicate which ecosystem service categories you are **directly studying** in your Earthwatch research and provide further details in the box below as needed.*

Provisioning Services
- ☐Fisheries (Fresh & Marine)
- ☐Energy (Fuelwood/hydropower)
- ☐Livestock grazing
- ☐Material extraction (resin, grass)
- ☐Timber
- ☐Water supply
- ☐Other food (crops, wild foods, spices)
- ☐Pharmaceuticals

Regulating & Support Services
- ☐Carbon sequestration/storage/"blue"
- ☐Coastal protection
- ☐Erosion control
- ☐Flood regulation/protection
- ☒Pest and disease control
- ☐Pollination
- ☐Seed dispersal
- ☐ Water purification/quality
- ☐ Nutrient cycling

Cultural Services
- ☐Cultural/historical values
- ☐Health (mental & physical)
- ☐Research & knowledge
- ☐Recreational
- ☐Spiritual/aesthetic values

Other Services
- ☒Biodiversity
- ☐Employment/Livelihoods

Details:

We continued to utilize a methodology that combined data using completely standardized methods in Costa Rica, Ecuador, Brazil, Argentina, Peru, and the United States to create plant-caterpillar-parasitoid diversity databases that can be used by land managers to search for natural enemies of agricultural pests and to examine relationships between enemy diversity and outbreak potential. Parasitoids provide an important, yet mostly unquantified ecosystem service that needs to be documented globally before it is enhanced, restored, or maintained. This is especially true for the tropics where pesticide inputs are not regulated and used in large quantities relative to temperate agricultural systems.

Conservation of cultural heritage

Provide details on intangible or tangible cultural heritage components that your project has conserved or restored in the past year.

Cultural heritage component[9]	Description of contribution	Resulting effect

9. Cultural heritage component options: traditional agriculture, artifacts, building(s), hunting ground or kill site, traditional ecological knowledge and practices, monument(s), oral traditions and history, spiritual site, traditional subsistence living

Impacting local livelihoods

Provide details on how livelihoods were impacted by your project. This includes persons hired to assist Earthwatch teams (field assistants, guides, cooks, drivers, etc.) and any economically applicable training provided to local community stakeholders.

Local livelihood impact(s)	Description of contribution	Number of people impacted
Provide opportunities for work	Our projects support the employment of the kitchen, maintenance and lodging staff and local parataxonomists . Our sizable projects are critical to the overall annual income earned by these rural families. In particular our projects provide opportunities for the employment of women. At the Costa Rica site we are able to support a local paratoaxonomist.	8 (2 parataxonomists, 3 Yanayacu kitchen staff, 3 lodging staff)

Please provide any other measurable actions that you conducted within the local community(s) where your research takes place.

We worked with Cal Tech students to create a coloring book that outlined the research taking place at La Selva Biological Research Station. These coloring books are going to be made available to students that attend schools near the station in Puerto Viejo, Costa Rica.

RESEARCH PLAN UPDATES

Report any changes in your research since your last proposal/annual report. For any ‘yes’ answers, provide details on the change in the ‘Details’ box. This section will not be published online.

1) Have you added a new research site or has your research site location changed? ☐Yes ☒No
2) Has the protected area status of your research site changed? ☐Yes ☒No
3) Has the conservation status of a species you study changed? ☐Yes ☒No
4) Have there been any changes in project scientists or field crew? ☒Yes ☐No

Details – provide more information for any ‘yes’ answers

Facilitator staff has changed. Andrea Glassmire and Nick Pardikes have since graduated and we have added new graduate student facilitators: Nadya Muchoney and Tanner Matson

5) Provide details on any changes to your objectives, volunteer tasks, or methods, include reason for the change.

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