EARTHWATCH INSTITUTE

Impact of Global Change on Pollinators and Pollination Services

Peters, V.E., Eastern Kentucky University

2016-2017

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Dear Volunteers of Pollinator Conservation in Costa Rica,

First and foremost I'd like to start off by saying THANK YOU to all of you for your excellent and very hard work in collecting so many cool bees and butterflies of Costa Rica! As I'm sure you can probably all guess it will take us many more months of sorting bees and identifying them before we can even start to put numbers on the total number of species we collected during the 2017 field season. We have only very recently finished pinning, cataloging, and counting all bees from the 2017 field season and will now begin the process of species identifications for 2017! What I can say for now is that in previous years of surveying bees over the elevational gradients from 2012 to 2015, working alone I was only able to collect on average 300 individuals per year, while in 2016 with the help of volunteers conducting surveys we collected a total of 2,945 bees and in 2017 we collected a total of 2,333! These numbers will greatly improve our estimates of population trajectories for many of the native bee species of Costa Rica!

Although we have not yet been able to identify to species all the bees from 2017, we have focused on the subset of bees that were hand collected from the Osa Peninsula work, to examine which plant species performed better in terms of supporting pollinators. We found that in June and July 2017 we collected a total of 554 bees from 33 different species that visited the 6 plant species we sampled. From this data we were able to construct species accumulation curves and the plant-pollinator network to determine which plant species would be best to recommend to conservation and restoration practitioners for pollinators.

With the help of Jose Montero at the UGA field station we were able to identify all the butterflies collected during the 2017 field season. In 2017 we collected 504 individuals representing 95 different species! A special thanks also to the volunteers who helped with the taking pictures of butterfly morphospecies and the fast paced data entry of the butterflies!

In conclusion, we have lots more work to do in the lab on bee identification, but we are very excited to have the data that you have helped us collect and are looking forward to bringing you more updates on our data, as well as some of our first publications from the data which we hope to be working on finalizing in late Spring or early summer 2019! Thank you all again so much!

Dr. Valerie E. Peters

SUMMARY

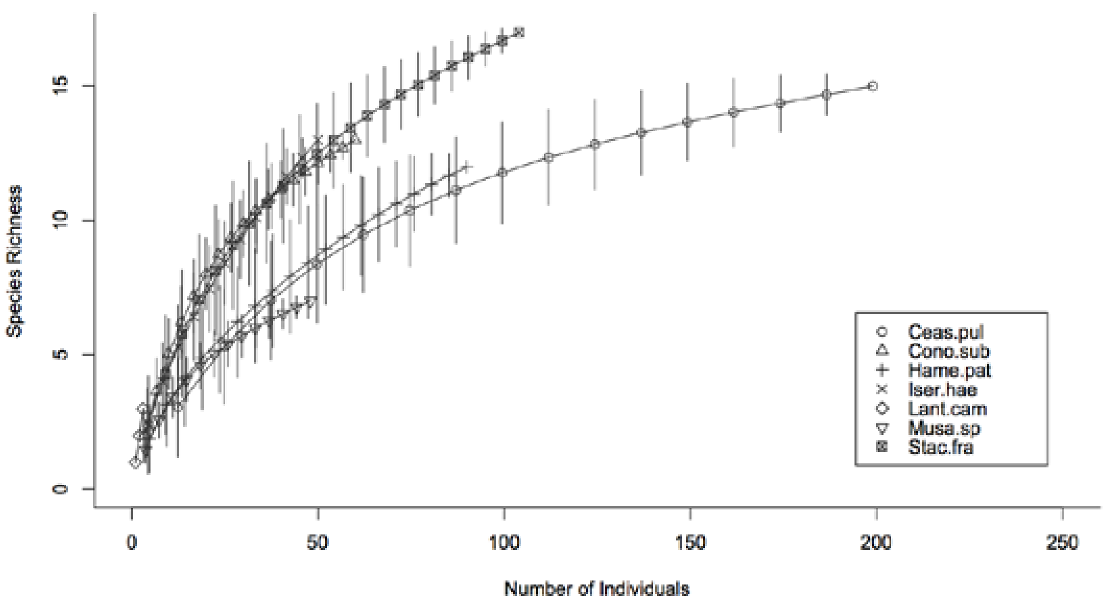
Working with invertebrates, such as bees and butterflies, does not permit immediate quantification of data collected during a field season, as all of our specimens from the June and July 2018 field season are currently being processed, pinned, and counted in the lab. Our 2017 and 2016 specimens however have been largely processed and some are still awaiting identification, and these results can inform what results we will likely obtain from the 2018 field season as well.

GOALS, OBJECTIVES, AND RESULTS

Osa Peninsula Field Site

Preliminary analysis of pollinator communities collected from flowering shrubs on the Osa Peninsula indicate that co-planting several species together may improve the restoration success of pollination services compared to the planting of any single shrub species regardless of the duration of the flowering season, including those species that flower continuously during all months of the year. First, species accumulation curves of bees collected from six flowering shrub species show that even after 101, 30-minute observation periods, or a total of 50.5 hours of catching bees, we still had not sampled the full species richness of pollinator communities for any of the six plant species (Figure 1).

Figure1. Species accumulation curves for six flowering shrub species occurring in the Osa Peninsula of Costa Rica. Curves have been rarified to account for the differences in the abundance of bees that were collected from the plant species. Curves are also rescaled to the number of individuals on the x-axis. Vertical lines represent 95% CIs for the species estimates.



There were a total of 554 bees representing 33 species that were collected from the flowering shrubs during the observation period that included June and July 2017. In addition, a total of 210 butterflies representing 37 species were collected from the flowering shrubs during the observation period that included June and July 2017. Network analysis of the bee-plant network indicates that the flowering shrub species shared many partners (i.e. bees) across the network (Figure 2). In fact, no compartments were found within the network. The most well connected shrub species, or the shrub species with the highest number of interactions was *Caesalpinnia pulcherrima* (199 interactions) and the shrub species with the highest diversity of interactions was *Stachytarpheta frantzii* (2.1 diversity index). The bee species with the highest number of interactions was *Trigona fulviventris*, which was not only very abundant but was also collected from all six of the flowering shrub species. This bee species would be considered a super-generalist in terms of the network.

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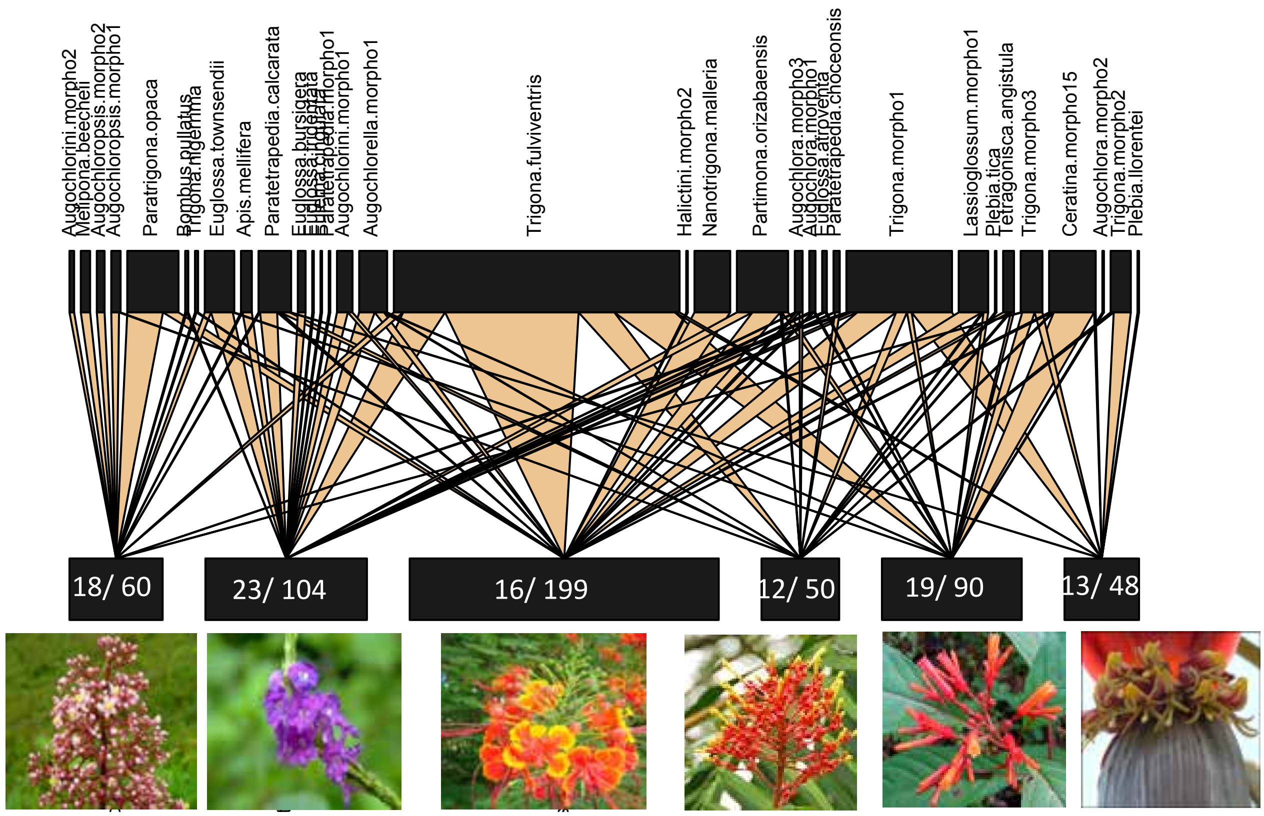
Figure2. Plant-pollinator network for six flowering shrub species occurring in the Osa Peninsula of Costa Rica. Species names on upper level show the names of all bee species collected from the flowering plants. The width of the black bars below bee species names indicate the abundance of the bee in the observed network. Tan/black connecting lines indicate that an interaction between a particular bee species and a particular plant species was observed, and the width of the line indicates the frequency that the interaction was observed. The six black bars at the base of the interactions each represent one of the flowering plant species observed, with a picture of that particular plant species below the bar. The width of the bars represents the number of interactions observed for that plant species. Numbers on the lower black bars indicate (a) how many 30-minute observation periods were conducted on each of the flowering shrubs and (b) the total number of bees that were collected from the plant species.



Despite the high number of shared pollinator species amongst the six flowering shrubs, indices of community similarity show that the bee community may benefit from the co-planting of several of the shrub species together in restoration and conservation applications. For example, *Conostegia subcrustulata* had consistently low similarity in bee community composition with the other shrub species and certain combinations such as *Musa* spp. with *Stachytarpheta frantzii* were also low (Table 1). Taking all of these observations together, thus far, our recommendations for restoration and conservation practitioners will be to plant a core of shrubs with an extended flowering duration, in combinations, for example, to plant *C. pulcherrima*, *S. frantzii*, and *C. subcrustulata* together, or *H. patens*, *S. frantzii* and *C. subcrustulata* together, and then to intermix with shrubs of short-term flowering duration. However, if space is limited for planting a variety of species, and only one plant species can be planted then we will recommend to plant the shrub species with either the highest number of bees recorded as visitors (*C. pulcherrima*; Figure 2) or the highest diversity of bee visitors (currently a tie between *S. frantzii*, *I. haenkeana*, and *C. subcrustulata*; Figure 1)

Table 1. Chao similarity indices calculated to compare bee community composition between each plant species observed

	C. pulcherrima	*C. subcrustulata*	*H. patens*	*I. haenkeana*	*L. camara*	*Musa sp.*
C. subcrustulata	0.43	-	-	-	-	-
H. patens	0.74	0.23	-	-	-	-
I. haenkeana	0.86	0.27	0.71	-	-	-
L. camara	1.00	0.22	0.98	-	-	-
Musa sp.	0.45	0.19	0.72	0.82	0.67	-
S. frantzii	0.55	0.26	0.56	0.78	0.40	0.36

San Luis de Monteverde Field Site

A total of 2945 bees were collected in 2016, and a total of 2333 bees were collected in 2017. Totals include all sampling seasons per year including June-July and December of each of the two years. Table 2 shows the distribution of the abundance of bees within selected bee tribes that were collected from the various sampling methods, comparing the two years, 2016 and 2017. Some interesting trends can be noticed from the table. First, after improving upon our methodology for hand collecting stingless bees with a honey solution between 2016 and 2017, there was a dramatic increase in the number of stingless bees (tribe Meliponini) that were hand collected from the honey solution in 2016 (77 individuals) compared to 2017 (593 individuals). This large increase shows that we were able to effectively increase our sample size of this very important Neotropical pollinator group, with the help of Earthwatch volunteers present at the various elevations to monitor these stations. The increase in sample size (higher abundance) of Meliponini, specifically, will greatly improve our ability to accurately evaluate population trends in stingless bees over time, and to better understand elevational specialization in stingless bee species as well as how stingless bee populations may be affected by a changing climate. As soon as species identifications are completed for the 2017 bees, we can begin our first assessments of Meliponini species' elevational range specialization and population trend analysis.

Table 2. Total abundance of bees from selected tribes collected across elevational gradient in San Luis de Monteverde

	Bee Abundance									
	Total		Bee bowls		Hand collected		Vane Traps		Timed Sampling	
Tribe/Family	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Apini	22	122	2	3	20	115	0	1	NA	3
Bombini	1	0	1	0	1	0	0	0	NA	0
Centridini	4	0	4	0	2	0	2	0	NA	0
Ceratinini	2096	663	2053	547	35	84	8	14	NA	18
Eucerini	4	9	2	6	0	1	2	2	NA	0
Euglossini	62	131	34	16	7	14	21	42	NA	59
Halictidae	603	483	581	342	21	104	1	10	NA	27
Megachilidae	7	47	1	9	6	30	0	8	NA	0
Meliponini	83	713	5	8	77	593	1	14	NA	98
Xylocopini	2	0	0	0	1	0	1	0	NA	0

In addition to increasing the abundance of collected bees, the presence of Earthwatch volunteers at the various elevations has also increased our ability to detect more species in the area, but exact results of species richness for 2017 is still awaiting identification for all pinned specimens. For now we can say that in other key groups we have added in hundreds more specimens via the hand collection method; for example, within the Family Megachilidae, this family, like the tribe Meliponini, is particularly underrepresented in bee bowl collections (Megachilidae captures from bee bowls in 2016 and 2017 total 1 and 9, respectively). Hand collection of Megachilids from 2016 and 2017 added an additional 6 and 30 individuals, respectively. This additional data will allow us to better estimate Megachilid species richness in the area. However, owing to the low rates of capture for Megachilid species (likely because they tend to be rare in the area or have low population densities), evaluating trends in population trajectories will not be feasible for Megachilid species.

In Monteverde, one bee tribe (Tribe Ceratinini), in particular, has allowed for some preliminary insight into some patterns. The bee Tribe Ceratinini includes some of the most abundantly collected species in our dataset, as well as the only tribe for which we have been able to identify all species, owing to our collaboration with Dr. Sandra Rehan at the University of New Hampshire, who is the world's leading expert on Ceratinini bees. Our data on bees in the Tribe Ceratinini indicate that long-term data collection will be needed to quantify population trends in some groups of bees, owing to their naturally fluctuating population numbers. For example, bee populations within the Tribe Ceratinini (small carpenter bees) show high fluctuation in abundance over the 12 samples collected thus far (Figure 3). Over 1200 individuals were collected during one week of sampling in June of 2016, and relatively high numbers continued to be collected into early July of 2016 compared to more typical numbers of <200 individuals during other collection periods. Preliminary analysis of elevational range specialization in species of the Tribe Ceratinini indicates that species are displaying strong associations with particular elevations within the study area (Figure 4).

Figure3. Population fluctuations in populations of some species in the bee Tribe Ceratinini, as observed from capture rates in bee bowls across three replicate transects spanning an elevational gradient of 800 m.a.s.l. to 1100 m.a.s.l.

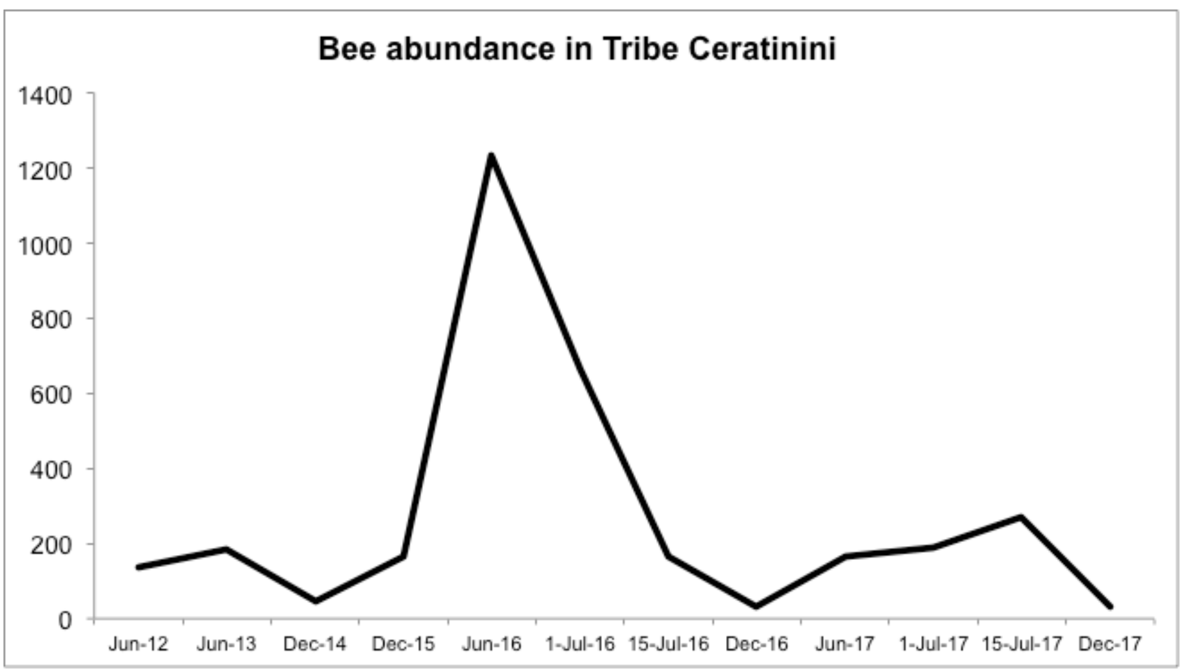
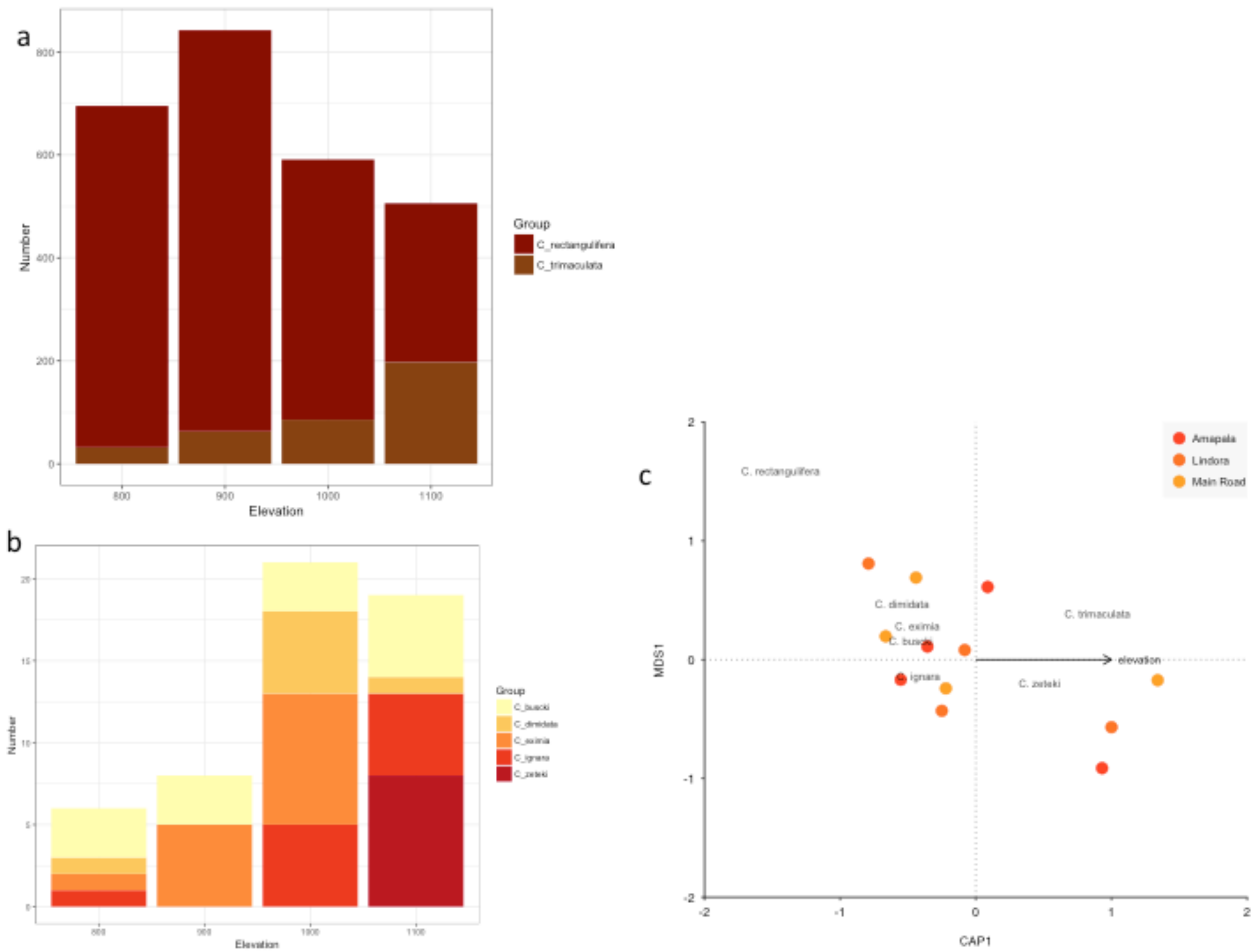


Figure 4 (a-c). Species patterns in bees of the Tribe Ceratinini (a) abundance across elevation of two most abundant Ceratinini species; (b) abundance across elevation within 5 other less common Ceratinini species; (c) community composition of Ceratinini species constrained by elevation.



PROJECT IMPACTS

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

1. Increasing Scientific Knowledge

a) Total citizen science research hours

We estimate that on average, volunteers worked daily from 8am to 3pm or a total of 7 hours per day. Some days included nightly lectures to bring that total to approximately 8 hours per day. With each volunteer team spending a total of 5 or 5.5 days in the field and a total of 8 volunteer teams during each of the 2016 and 2017 field seasons, the total number of citizen science research hours for June-July and December 2016 ranges between 280 hours and 352 hours and for June-July and December 2017 ranges between 280 hours and 352 hours, not including the time of each groups initial travel to and departure from each of our field sites, Monteverde or the Osa Peninsula.

b) Peer-reviewed publications

c) Non-peer reviewed publications:

Technical reports, white papers, articles, sponsored or personal blogs

d) Books and book chapters

e) Presentations:

Peters, V.E. 2017. Invited Speaker, Bees and Pollination Services, Department of Biology, Centre College, November 2017

Fleitz, A., and V.E. Peters. 2017. Pre-montane altitudinal range limitation in Small Carpenter Bees (Tribe Ceratinini) in Costa Rica. UK CEEB Symposium, EREC, University of Kentucky.

Fleitz, A., and V.E. Peters. 2016. Using network theory to inform ecological restoration in the Neotropics. Ecological Restoration Symposium. Missouri Botanical Garden

2. 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
Chelsea Hinton	M.S.		2019

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	Details on contributions/ activities

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)
University of Georgia	Logistics, Permits, Academic support	2005 to present
Osa Conservation	Logistics	2016 to present
Finca Kobo	Collaboration	2014 to 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

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
5. Stage of plan/policy options: proposed, in progress, adopted, other (define)

5. Conserving natural and sociocultural capital

a) Conservation of taxa

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

Species we work with are insects and IUCN status is unknown

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

b) 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]

[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

c) Ecosystem services

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

☐ Food and water

☐Flood and disease control

☐Spiritual, recreational, and cultural benefits

☐Nutrient cycling

Details:

We are studying the ecosystem service of pollination

d) 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

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

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

ACKNOWLEDGEMENTS

We thank the many Earthwatch volunteers who braved rainstorms and extreme heat to help us gather this data. We also thank the many farmers and private landowners who have supported our projects, especially Oldemar Salazar, Eliza Mata, and Alex Retana.