2013 NPS George Melendez Wright Climate Change Youth Initiative Fellowship and Internship Program

FELLOWS' FINAL RESEARCH REPORTS

DECEMBER 31, 2015

Submitted by the University of Washington
Principal Investigator: Lisa J. Graumlich

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2013 NPS George M. Wright Climate Change Youth Initiative
Fellowship Research Final Report
December 31, 2014

Fellow Name: Mariana, Abarca Zama
University: The George Washington University
Start date: June 2014
End date: December 2014

Brief project summary:
Phenological shifts and the subsequent disruption of biotic interactions they provoke are among the most evident effects of climate change. The goal of my study is to determine the potential for mismatch between eastern tent caterpillars (*Malacosoma americanum*, ETC hereafter) and their main host plant (*Prunus serotina*) as a consequence of global climate change, and to identify the environmental restrictions ETC are likely to face along their distributional range as a consequence of rising temperatures. In particular, my research focuses on: i) Documenting the phenology of ETC and black cherry trees in Rock Creek Park; ii) identifying temperature-related physiological restrictions at different stages of ETC development; iii) assessing the fitness consequences for ETC of early and late hatching; and iv) incorporating this information into a niche model to predict the geographic areas where ETC are more likely to undergo population changes. This study involved ETC sampling in four national parks (Chattahoochee River National Recreation Area, Rock Creek Park, the Ice Age National Scenic Trail and Acadia National Park) four state parks and several private properties.

Research Approach:
My work to date is generally consistent with my original proposal, however there was an unforeseen event that made the study more complex and the data set more valuable. Many of the egg masses included in my sampling where attacked by parasitoid wasps, so now I'm able to analyze the phenological responses of a third throphic level (wasps) in addition to the caterpillars and plants, as was originally proposed. This is an important improvement because, to my knowledge, there are no other studies simultaneously evaluating the responses of hosts an their parasitod wasps to climate warming in a controlled setup.

Another deviation from the original plan is that I added Acadia National Park to the sampling of egg masses and I did not visit the Appalachian trail. My trip to the Appalachian trail was scheduled during the government closure, so I relocated the sampling to Blandy experimental Farm (University of VA).

Location(s) of Research:
Phenology of eastern tent caterpillars and black cherry trees:
Rock Creek Park

Collection of egg masses of eastern tent caterpillars

National Parks:
Rock Creek Park, DC
Acadia National Park (ME)
Ice Age National Scenic trail (WI)
Chattahoochee river national recreation area (GA)

Other sites:
Withlacoochee State Forest (FL)
Groton State Forest (VT)
Blandy experimental Farm (VA)
University of Florida, Gainesville (FL)

Key Findings:
Two thirds of the data gathered for this project are still in the processing and analysis stage, so they are not summarized here. The findings below correspond to the abstract of the first chapter of my dissertation, which has been submitted for publication to the journal Global Change Biology.

Climate change is altering fundamental interactions among plants and insects by changing the timing of key phenological events, such as budburst and flowering for plants and hatching and emergence for insects. We combined field phenology observations with laboratory manipulations to provide a comprehensive view of the effects of climate change on a temperate forest herbivore, eastern tent caterpillars (*Malacosoma americanum*). We recorded the spring phenology of wild caterpillar colonies and their host plants, and conducted laboratory assays to determine if caterpillars are using plant chemical cues to fine-tune their hatching time. We also evaluated individuals from two distant populations (Washington, DC and Roswell, GA) to assess the effect of warmer winter and spring temperature regimes on caterpillar hatching patterns and starvation endurance, a trait likely to be under selection in populations experiencing phenological asynchrony. Finally, we measured the long-term effects of early food deprivation on development time and pupal mass. In the field, hatching and budburst occurred earlier in 2013 than in 2014 and the period with optimal foliage quality was shorter in 2013 (the warmer year). Experimentally, warm temperatures induced early hatching time and caterpillars did not respond to foliage cues to time their hatching. Caterpillars from GA were able to survive starvation periods that were 30% longer than caterpillars from DC. Warmer post-hatching regimes reduced the starvation endurance of caterpillars overwintering in the wild but not in the lab. Early starvation diminished hatchling survival, however, surviving caterpillars did not show detrimental effects on pupal mass or development time. We found that warmer temperatures can trigger late-season asynchrony, even when budburst and hatching are synchronous, by allowing faster foliage development. Our results also show that distant populations are differently equipped to cope with environmental unreliability and therefore are likely to differ in their response to climate change.

Deliverables/Research Products:

Completed Research products

Abarca, M., Lill T. J, 2014. How will Eastern tent caterpillars react to climate change?. ESA 99th Annual meeting, Sacramento, California. Natural history chapter award honorable mention (http://esanaturalhistory.wordpress.com/2014/09/). http://eco.confex.com/eco/2014/webprogram/Paper47529.html

Research products in progress

Display at RCP Nature Center- The final version has been approved by the RCP Nature Center staff and will open to the public in mid-November.

Abarca M. and Lill J. 2014. The effects of warming on hatching time and early season survival of eastern tent caterpillars. In review (Global Change Biology).

Webinar for NPS staff- Spring 2015 (to be scheduled)

Manuscript 2 in preparation- May 2015.

Manuscript 3 in preparation- May 2015.

Oral presentation at the George Melendez Wright Conference, 2015, CA

Oral presentation at the 100th Annual meeting of the Ecological Society of America, Baltimore, MD, August, 2015

Additional Funding:

I applied for a small grant to do a complementary study from the Washington Biologist's Field Club, $992.00.
I'm applying for the Smithsonian Environmental Center (SERC) postdoctoral fellowship to continue doing climate change research using the same study system.

Other:

- I gave a talk about eastern tent caterpillars and their phenology to the insect zoo volunteers at the National Museum of Natural History on Wednesday, July the 10th, 2013. I also presented two posters at the summer research poster presentation organized by the Biology Department of the George Washington University on October the 4th, 2013 and on October the 3rd, 2014 .

- Please share any anecdotes or stories from your project -- surprising discoveries, interesting happenings in the field, etc. -- that you think would be especially interesting for a general audience.

Female parasitoid wasps insert their eggs into their hosts and the larvae feed on the host's tissue eventually killing them. Larvae are selective and consume the non-vital tissue first, keeping the host alive and fresh as long as possible. There are several wasp species that attack the eggs of eastern tent caterpillars. While doing my research I dissected some eggs infested by parasitoids and I found that these wasps were attacked by other parasitoid wasp! The parasitoids that feed on other parasitoids are called hyperparasitoids. This is the first time this interaction has been formally documented for eastern tent caterpillars.

Photographs:
Please include 3-5 photographs from your project. We are especially interested in any photos of you doing your research.
** In doing so, you are granting the University of Washington and the National Park Service permission to use your photos in publications (web, electronic, or print) related to the George M. Wright Climate Change Youth Initiative.*

Collecting egg masses

2013 NPS George M. Wright Climate Change Youth Initiative
Fellowship Research Final Report
December 31, 2014

Fellow Name: Jeffery B. Cannon
University: University of Georgia, Plant Biology Dept.
Start date: 5/15/2013
End date: 12/31/2014

Brief project summary:

Wind damage can affect 1.6 million ha of forest annually, leading to substantial damage to some national parks and causing closure of parks for costly repairs and limiting visitor access. For example, in October 2012, over 70 national parks closed for repair following Hurricane Sandy. In February 2011, a tornado struck portions of the Great Smoky Mountains National Park, closed trails, and cost over $800,000 in repairs. Thus, giving park resource managers more information on the extent, and pattern of current damage as well as information on physiographic settings vulnerable to future damage allows them to make optimal resource allocation decisions to manage those disturbances.

In this project, I developed a method to convert aerial photographs of tornado-damaged areas in Great Smoky Mountains National Park into a detailed map of damage severity. The damage severity map was overlaid with maps of topography to determine which factors increase damage severity in the park. In this project I am also using the damage severity map to analyze the number, size, and severity of damaged patches to gain a better understanding of how wind damage may influence landscape-scale vegetation patterns. Because the extent and disturbance pattern of disturbances from tornados is relatively unknown, understanding the extent and pattern of individual disturbances can allow better estimation of baseline data on the size, extent, and risk damage following natural disturbances.

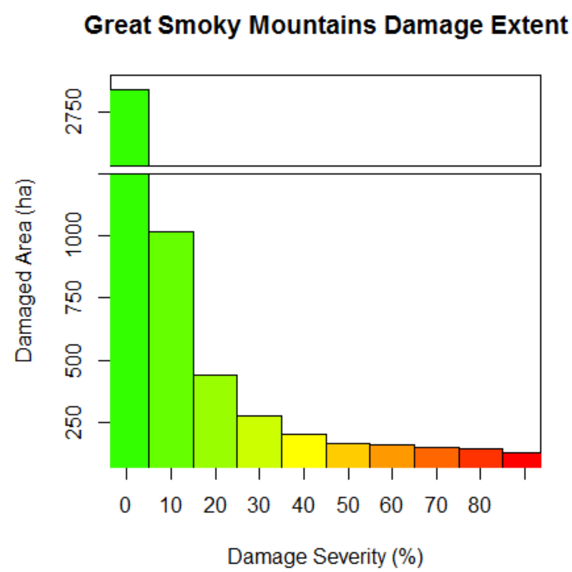
Research Approach:
The basic questions of this research project remain relatively unchanged. The largest component of the work was to develop a method to convert aerial photographs of tornado damage into a detailed map of damage severity. The overall approach using Supervised classification remains, but we have improved the approach to use multiple different sets of training data to classify the aerial photograph and then average these classifications together which allows for internal validation of the photograph. Once the classified map was created, we used the map to measure the extent and distribution of tornado damage as well as analyze the landscape-scale pattern of tornado damage. The final aspect of the project was to relate a map of damage severity to several factors such as topography, vegetation, and soil types. However, proper analysis of this dataset requires careful consideration of spatial autocorrelation between data points and requires a computationally intensive analysis. Because of this constraint, we have limited the current analyses to relate how damage severity responds to topography because increasing the number of explanatory variables greatly increases the computational time needed to

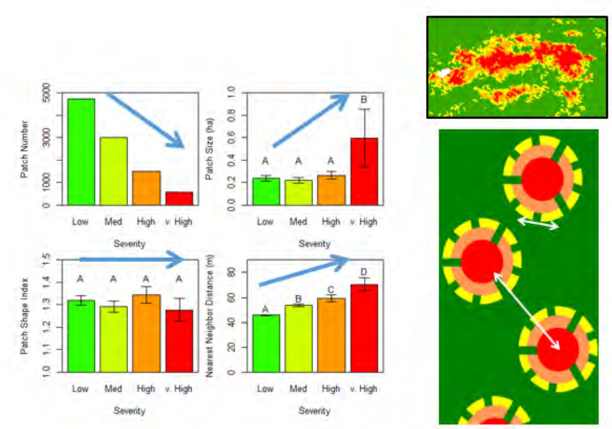
complete the analysis. For example, because of the computational complexity of spatially explicit statistical models, the analyses we present were completed after several weeks using a super-computer. Adding additional factors can rapidly and exponentially increase computational time.

Location(s) of Research:
All field research for this project is done at Great Smoky Mountains National Park. At the Park we collected field measurements of damage severity in approximately 30 plots to validate the aerial classification. In addition, we have similar data for a tornado-damaged site in north Georgia, in which I am running parallel analyses. Thus, not only have we analyzed the damage patterns at GSMNP, analyses comparing the GSMNP tornado to the north Georgia tornado are underway.

Key Findings:

- Using supervised maximum likelihood classification, we developed a method to remotely measure tornado damage from aerial photographs which may allow large-scale estimate of the damage extent of tornados.
- We found that in the affected area, approximately 750 ha received >50% loss of basal area while 1400 ha received >25% loss of basal area.
- Interestingly, damage severity was somewhat uniformly distributed with damage distributed approximately equally in all damage severity classes greater than 30%. In other words, approximately equal amounts of land area received severe, heavy, and medium damage. However, very light damage (10–30%) also affected very large areas. See figure above.
- Most forest tornado gaps were very small (<1 ha), but some gaps were greater than 450 ha.
- When examining the landscape pattern of tornado damage, we found that forest gaps created from tornado damage exhibited a "dissolved bulls-eye" pattern with severely damaged patches nested within less severely damaged patches, and with patch size highest in severely damaged gaps. See figure and diagrams to the right.





- We found that many topographic variables such as slope, aspect, and topographic position all were apparently correlated with tornado damage, as has been found in other studies of wind damage. However, when incorporating appropriate statistical models that account for spatial autocorrelation between patches of nearby damage, we found that only slope was a good predictor of tornado damage, with flatter slopes (such as those found in valleys and ridge-tops) having higher levels of damage than steeper slopes.
- Because approximately 1300 tornados occur each year, a method to remotely measure the extent and severity of tornados can allow an estimation of the regional carbon impact of tornados annually.

Deliverables/Research Products: (Please list.) This may include, but is not limited to presentations at the park(s), conferences/meetings attended, interpretive talks, published articles, electronic education products, etc.

Include the links to any of your research products that are available electronically. If they are print products, please attach them at the end of this report as appendices.

Research from two 27 April 2011 tornados in Southern Appalachians forests [preliminary findings of Park research presented by CJ Peterson and C Godfrey to the GSMNP Staff during brown-bag lunch]	**July 2013**
Crash and burn: Patterns of forest tornado damage and its interaction with fire. *Presented at the Southeastern Ecology and Evolution Conference, Statesboro, GA*	**March 15, 2014**
Oh the damage done: Assessing patterns of wind damage in the Great Smoky Mountains. *Oral Presentation at the Great Smoky Mountains National Park Science Colloquium, Gatlinburg, TN*	**March 20, 2014**
Crash and burn: the influence of wind damage and landscape pattern on forest fuels and fire behavior. *Poster presentation at the Ecological Society of America Meeting, Sacramento, CA.*	**August 15, 2014**
Wind disturbance in a changing world: Wind damage patterns in Great Smoky Mountains National Park. *Climate Change Research from the Next Generation: Climate Change Fellowship Science in Parks*, webinar.	**November 13, 2014.**

Additional Funding:
Were you able to use the Fellowship as leverage for securing other research funding? If so, please list the sponsor, program, and the amount of funding.

Other:

- Please include information about additional products, presentations, or outcomes related to this research project that are not otherwise included in this report.

- Please share any anecdotes or stories from your project -- surprising discoveries, interesting happenings in the field, etc. -- that you think would be especially interesting for a general audience.

Photographs:
Please include 3-5 photographs from your project. We are especially interested in any photos of you doing your research.
** In doing so, you are granting the University of Washington and the National Park Service permission to use your photos in publications (web, electronic, or print) related to the George M. Wright Climate Change Youth Initiative.*

CRW_0021: Chris Peterson (foreground) and Jeffery Cannon (background) examine a large tip-up mound created from the uprooting of a large tree. Photo Credit: Christopher Godfrey

CRW_0023: Jeffery Cannon measures the diameter of a large tree in a lightly damaged area of the Park
Photo Credit: Christopher Godfrey

CRW_0046: Jeffery Cannon (right) takes notes from two field helpers, undergraduate student Michael Bailey (center) and graduate student Uma Nagendra (left). Photo Credit: Christopher Godfrey

IMG_0006.jpg: Jeffery Cannon (background) and labmates set up plots for measuring damage severity in Great Smoky Mountains national park. In the foreground from left to right are Nick Richwagen, Uma Nagendra, and Michael Bailey. Photo Credit: Christopher Godfrey

IMG_0066.jpg: An area in Great Smoky Mountains National Park two years following severe tornado damage on April 27, 2011. Photo Credit: Christopher Godfrey

2013 NPS George M. Wright Climate Change Youth Initiative
Fellowship Research Final Report
December 31, 2014

Fellow Name: Amber Churchill
University: University of Colorado Boulder
Start date: May 24th, 2014
End date: December 31st, 2014

Brief project summary:

My project focuses on measuring the presence of an ambient nitrogen deposition gradient in the Rocky Mountains of CO and WY, how this gradient may interact with changes in water availability and snow pack with weather anomalies and the responses of alpine moist meadow plant communities to these environmental changes that may be indicative of future climate scenarios. The questions that I am looking at include 1) how changes in winter precipitation (timing and amount) alter ecosystem nitrogen availability and plant-soil interactions;2) does the nitrogen deposition gradient translate into ecosystem and community responses with increased nitrogen availability, and 3) are feedbacks between plants and soil constant along the gradient of nitrogen deposition?

Questions 2 and 3 are the subject of a paper that is targeted for submission in the early half of the spring 2015 semester, and Question 1 is the focus for a follow up paper looking at explanations of inter-annual variability in the data collected along the nitrogen gradient between 2012 and 2014 (target journal submission summer 2015).

Research Approach:

Please describe any significant changes to the original questions, hypotheses, or approach you used in your research.

All changes to the research approach occurred in the first year of the proposed study (field season 2013), and are described in detail in the Fall of 2013 Status Report (due Oct 2013). There were no changes in questions, nor in hypotheses.

Location(s) of Research:

I conducted research in five locations through the central and southern Rocky Mountains, including:

1. Shoshone National Forest, Greybull Ranger District outside the town of Meeteese, WY
2. Rocky Mountain National Park, Mt. Ida
3. Fraser Experimental Forest (Forest Service Experimental Station within Arapaho National Forest), Fool Creek Watershed outside the town of Fraser, CO
4. Niwot Ridge Long Term Ecological Research site (University of Colorado Boulder experimental station within Roosevelt National Forest, CO)
5. Arapaho National Forest, near the trail for Gray's and Torrey peaks in CO

A sixth site was initially proposed for monitoring in Grand Teton National Park WY, however that plan was abandoned prior to the start of the 2014 field season (for details see Fall 2013 Status Report).

Key Findings:

Note that I am still waiting on results for samples associated with the 2014 field season

My initial analysis for samples has focused on understanding potential differences in site comparisons for data collected in 2012 and 2013 associated with research question 2. Future work with these results will focus on creating linear mixed models partitioning site differences in plant and soil responses associated with nitrogen deposition, climate, elevation, and soil texture. Initial findings show that there are some differences in summer amounts of N deposition between the five research sites, with Shoshone having the lowest levels of N deposition, and (**Figure 1**), and that my summer deposition estimates align with nationally modeled annual estimates of N based on PRISM, NADP, and CMAQ (Simkin et al., unpublished; **Figure 2**). Future analysis will include snow chemistry data for a subset of my sites to approximate annual deposition, and examine potential inter-annual variability associated with those estimates.

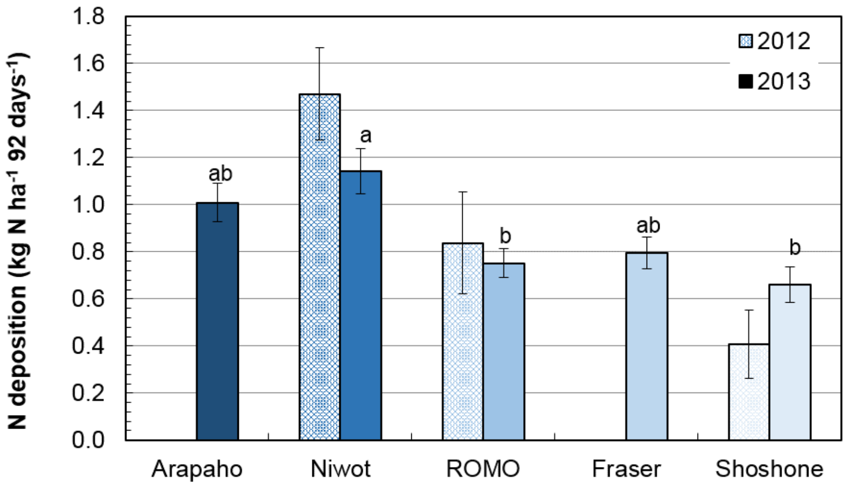


Figure 1. Mean field measured levels of nitrogen deposition from 2012-2013 using ion-exchange resin samplers installed in the field during summer months (standardized to 92 days), error bars are ± 1 SE. Non-significant differences among sites for 2013 are indicated with same letter designations.

Ecosystem responses to N deposition that I have analyzed thus far, show that sites receiving more N also show higher concentrations of soil water nitrate, lower soil cation exchange capacity, and lower soil pH (**Table 1**). Future analysis will examine the importance of N deposition as compared to site climate factors, as well as elevation and soil texture in different alpine meadows, in predicting these trends.

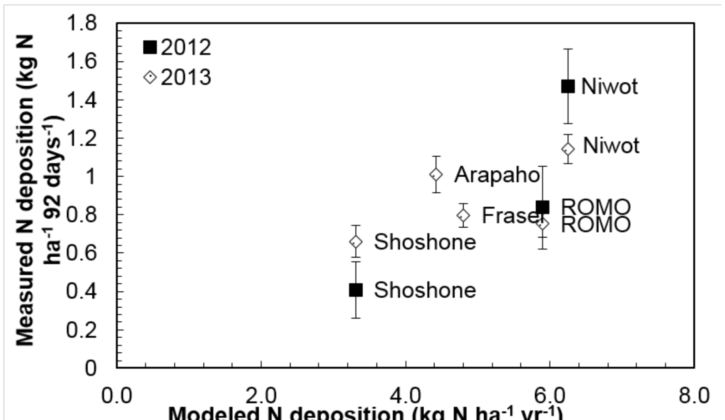


Figure 2. The relationship between N deposition based on regionally modeled NADP plus CMAQ data (Simkin et al., unpublished) and in situ measurements of N deposition using ion-exchange resin columns (R^2 = 0.439). Data shown are mean measurements, ± 1 SE.

Vegetation responses to N deposition that I have looked at so far include changes in species composition among the different sites and net primary productivity (NPP). I have

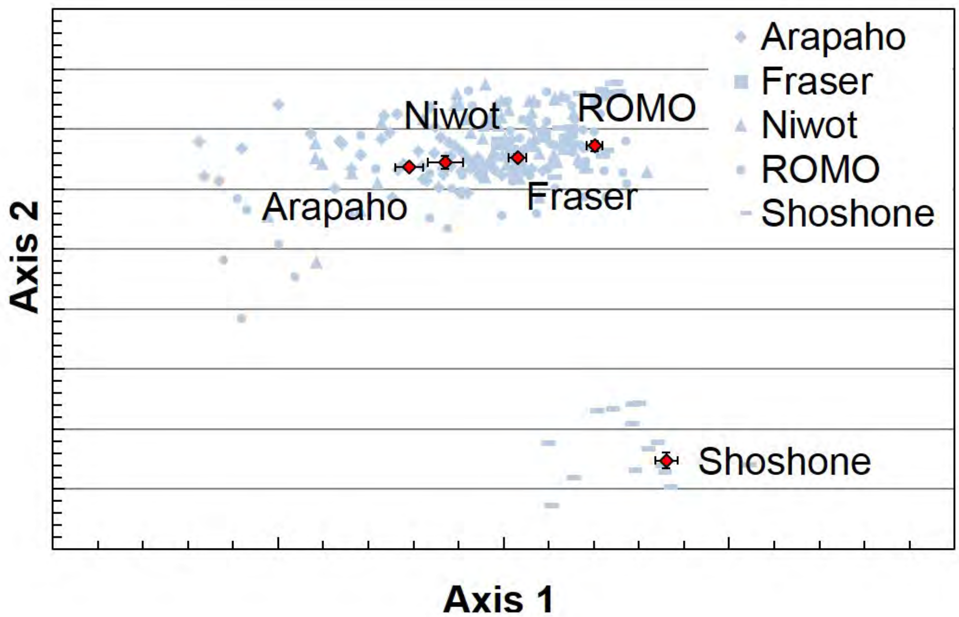


Figure 3. Non-metric dimensional scaling ordination of plant community composition among all sites. Final stress for 2-D solution was 12.63, with an instability of less than 0.0001. Mean ordination scores are shown in red, with SE bars shown for both axes.

found that all sites are different from one another in species composition (MRPP results indicate significant differences in composition among sites: A = 0.3, all p values < 0.001), with separation of sites by non-metric dimensional scaling into two main axes (**Figure 3**).

Although I have only finished processing samples for 4 of the 5 sites for NPP from samples collected in 2014, there are some differences between sites (**Figure 4**), especially between sites with different precipitation patterns (**Table 2**).

Figure 4. Mean NPP for sites compared along the N deposition gradient, error bars are ± 1 SE. Non-significant differences among sites for 2013 are indicated with same letter designations.

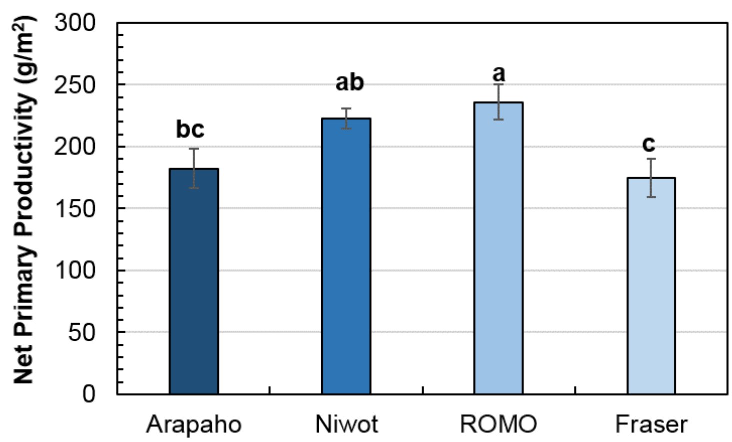


Table 1. Ecosystem metrics for evidence of ecosystem response to N deposition in the Southern and Central Rocky Mountains.

Site ID	Soil water [NO_3^- and NO_2^-] (mgN/L) Post snow melt±	Cation exchange capacity ($cmol_c$/kg)	Soil pH
Arapaho NF	0.44 ± 0.03[a]	9.6 ± 0.4[bc ±]	4.1 ± 0.04[bc ±]
Niwot Ridge LTER	0.19 ± 0.05[ab]	10.4 ± 0.4[bc ǂ]	4.2 ± 0.06[bc ǂ]
Rocky Mountain NP	0.20 ± 0.06[ab]	7.9 ± 0.6[c ǂ]	4.0 ± 0.04[c ǂ]
Fraser EF	0.16 ± 0.03[b]	13.8 ± 1.6[b ±]	4.5 ± 0.10[b ±]
Shoshone NF	NA†	21.5 ± 1.1[a ǂ]	5.3 ± 0.08[a ǂ]

* Same letters indicate non-significant differences in means
± Samples collected in the field during the growing season of 2013
ǂ Samples collected in the field during the growing season of 2012
† Soil water samples were not successfully collected from Shoshone NF

Table 2. Average climate conditions at each site along the N deposition gradient based on PRISM estimates.

Site	Annual Precip.	Annual T_{max}	Annual T_{min}
Arapaho	856.67	4.99	-7.2
Fraser	889	4.96	-7.51
Niwot	1067.81	4.42	-8.04
ROMO	1053.52	4.36	-8.01
Shoshone	709.05	3.89	-7.33

Deliverables/Research Products: (Please list.) This may include, but is not limited to presentations at the park(s), conferences/meetings attended, interpretive talks, published articles, electronic education products, etc.

Associated with this project I was able to give two presentations at scientific meetings, and I have submitted an abstract to the George Wright Society Conference in the spring of 2015. I will also be submitting an abstract to the Rocky Mountain NP Biennial Research Conference for the spring of 2015.

"Alpine moist meadow response to regional gradients of nitrogen deposition in the Rocky Mountains"
Ecological Society of America Annual Meeting; Sacramento, CA
Talk Author (Appendix A) Summer 2014

"Alpine moist meadow response to regional gradients of nitrogen deposition in the Rocky Mountains"
Guild of Rocky Mountain Ecology and Evolutionary Biologist Annual Meeting; Pingree Park, CO
Talk Author (Appendix B) Fall 2014

I am planning two research publications associated with the work, however both of these are currently in preparation and will not be submitted until the spring of 2015 at the earliest.

Churchill, A.C**.**, Ribarich, M.J.*, Bowman, W.D. *In Prep for Global Change Biology*. Alpine moist meadow response to regional gradients of nitrogen deposition in the Rocky Mountains.

Churchill, A.C., Bowman, W.D. *In Prep for Arctic, Antarctic, and Alpine Research*. Interactions between winter weather variability and nitrogen deposition on alpine moist meadows.

* indicates undergraduate co-author

Additional Funding:
Were you able to use the Fellowship as leverage for securing other research funding? If so, please list the sponsor, program, and the amount of funding.

Throughout the duration of this project I was fortunate to receive a number of additional grants associated with this project. Some of these grants were associated with funding opportunities to engage undergraduate students in conducting research, where the students worked at my field sites using the materials provided by the Fellowship and had their salary paid through a number of initiatives at the University of Colorado Boulder, including the grants listed below:

> The effect of nitrogen deposition on krummholz recruitment and establishment at alpine treeline. UROP Individual Grants ($2,400); Undergraduate Research Opportunities Program, University of Colorado Boulder with Colin Luben, and Dr. Bowman (*received*: 2013)
>
> Differences in herbivore presence between alpine meadow communities in the CO Rocky Mountains. UROP Individual Grants ($2,400); Undergraduate Research Opportunities Program, University of Colorado Boulder with George Libby and Dr. Bowman (*received*: 2013)
>
> Alpine moist meadow response to gradients of nitrogen deposition in the Rocky Mountains. UROP Team Grant ($2,400); Undergraduate Research Opportunities Program, University of Colorado Boulder with Dr. Bowman and Teal Potter (*received*: 2013)
>
> Alpine moist meadow response to gradients of nitrogen deposition in the Rocky Mountains. BURST Grant ($2,500); Biological Science Research Skills and Training, University of Colorado Boulder with Dr. Bowman and Drew Meyers (*received*: 2013)
>
> Alpine moist meadow soil responses to nitrogen deposition along a deposition gradient in the Rocky Mountains. UROP team Grant ($3000), Undergraduate Research Opportunities Program, University of Colorado with Dr. Bowman (*received 2014*)

I was also fortunate to receive associated funding to support related projects, although most of these awards were granted prior to my selection as a Fellowship recipient, or without the funding agency using the Fellowship as committed cost-sharing.

> Alpine moist meadow response to nitrogen deposition in the Greater Yellowstone Ecosystem. UW NPS Small Grant ($4290); University of Wyoming National Park Service Small Grant, CO PI Dr. Bowman (*received*: 2013-2014)
>
> Regional gradients of nitrogen deposition in the central and southern Rocky Mountains, USA and coupled vegetation-soil interactions in alpine moist meadows. Beverly Sears Bigelow Named Grant ($2000); Graduate School, University of Colorado Boulder (*received*: 2013-2014)
>
> Alpine moist meadow response to regional gradients of nitrogen deposition in the Rocky Mountains. David Paddon Grant ($1000), Indian Peaks Wilderness Alliance (*received 2014-2015*)

Other:

- Please include information about additional products, presentations, or outcomes related to this research project that are not otherwise included in this report.

I have been able to use photos and materials associated with this project to engage elementary school students in what it means to be a scientist in an outreach event.

> *Visiting Scientist for 'Being a Scientist Unit' at Park View Elementary School* (Auburn, ME), ~60 students: scientist in residence (October 22nd, 2014)
> I talked about what it means to be a scientist, using the scientific method, and the types of tools used by scientists as part of a question and answer session on skype with two 1st grade classrooms and one 2nd grade classroom.

- Please share any anecdotes or stories from your project -- surprising discoveries, interesting happenings in the field, etc. -- that you think would be especially interesting for a general audience.

As a field ecologist we expect that there will be differences in environmental conditions between years of sampling. Precipitation patterns will vary (in duration and amount), and temperatures may be very different between years and seasons. My project was designed to capitalize on differences in annual winter weather conditions in the alpine, and how those conditions might affect N deposition and consequent responses of the ecosystem including biotic and abiotic components. Little did I realize, however, that my study would incorporate drastically different snow pack years that would complicate my methods of data collection and even site access during the early parts of the summer 2014.

The snow pack for my sites in Colorado in May/June of 2014 were estimated to be 150% average annual snowpack. This meant that there were huge drifts and snowfields persisting much later into the summer than in the comparatively low snowpack year of 2012 (approximately 50% annual snowpack at Niwot Ridge LTER). Access at all sites is challenging to some extent in the early summer, with muddy trails and residual snow patches, however this past summer this also meant committed mountaineering across steep snowfield to access the (snow free) alpine through the shaded (and therefore snow filled) krummholtz. My crew lead assistant (Matthew Ribarich) and I spent long days on snow shoes, or in crampons, post-holing our way between trail heads in sub alpine forest into the alpine tundra. I am including some of the more epic photos here to show the drastic extent of snow from the 2014 season (see next section). The added snow did not, of course, prevent us from making the collections we needed, and in the end we decided we earned several extra cups of hot chocolate and meals at local Indian food restaurants to recover from our ordeals.

Photographs:

Please include 3-5 photographs from your project. We are especially interested in any photos of you doing your research. ** In doing so, you are granting the University of Washington and the National Park Service permission to use your photos in publications (web, electronic, or print) related to the George M. Wright Climate Change Youth Initiative.*

Figure 1. Our field vehicle stuck in the snow during our first visit to Fraser Experimental Forest in June 2014. Fellowship Recipient is trying to repair a torn skid cover with duct tape. Photo credit A. Churchill.


Figure 2. Matt Ribarich (on right; Crew Lead) and Fellowship Recipient standing by a snow drift along Trail Ridge Rd in Rocky Mountain National Park on the day of our first (failed) attempt to access the trail to our field sites on Mt. Ida. Photo credit A. Churchill.

Figure 3. Residual snow field at Shoshone National Forest in the Greybull Ranger District, in early July 2014. Despite visiting this site for three summers this was the most snow we experienced accessing the site, which is located up and to the right of this photo. We had to climb this snow field to access the site. Photo credit A. Churchill.

Figure 4. Fellowship Recipient (center in purple) and crew doing vegetation surveys at Fraser Experimental Forest in July of 2014. Photo credit S. Sternagel.


Figure 5. Building clouds over the plains east of Niwot Ridge LTER site during early August 2014. Matt Ribarich (Crew Lead) is located in the right corner of photo collecting aboveground biomass and net primary productivity. Photo credit A. Churchill.

2013 NPS George M. Wright Climate Change Youth Initiative
Fellowship Research Final Report
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Fellow Name: Hollie Emery
University: Boston University
Start date: June 2013
Report End date: December 2014 **Project End date: December 2015**

Brief project summary:
Precipitation changes, especially the intensification of precipitation events (e.g. longer droughts and stronger storms) are an important aspect of anthropogenic global climate change. The impact of precipitation intensification may be especially great in ecosystems that are chronically water stressed, either from extremely dry conditions, or from extremely wet conditions that lead to sediment anoxia. As tidal wetlands, salt marshes are subject to a variety of stressors including high salinity and anoxia, making them potentially very sensitive to changes in rain and other freshwater inputs.

Since April 2014 I have conducted an experiment to test the effects of precipitation change on salt marsh biogeochemistry. I used rainout shelters to intercept incoming rain, and instead deliver it to one of four precipitation treatments: ambient rainfall, doubled ambient rainfall, prolonged drought, or simulated intense drought with strong storms. In these 1.5 m^2 plots, we make monthly measurements of greenhouse gases, the overall productivity and root:shoot allocation of marsh grasses, and the cycling of silica and other nutrients through plants, sediment, and porewater. The primary objectives of this research are to determine 1) how climate-induced changes in precipitation (prolonged drought, doubled growing season totals, or drought with intense storms) will alter salt marsh ecosystem services such as carbon sequestration, nutrient cycling, and primary productivity, and 2) whether climate-induced changes in precipitation will alter the ability of salt marshes to keep up with sea level rise by effecting carbon cycling processes.

Research Approach:
Please describe any significant changes to the original questions, hypotheses, or approach you used in your research.

I have not made any significant changes to my approach since the 2013 Status Report. As planned, I established my experimental precipitation manipulations early this spring before plant growth commenced, I made monthly measurements/collections of ecosystem greenhouse gas fluxes and sediment, porewater, and biomass parameters, and I harvested end-of-season biomass to estimate annual primary productivity.

I have made some changes to the original questions and hypothesis stated in my proposal this season. My primary focus has continued to be on the carbon cycling of the system and the connection between carbon cycling and sea level rise. Along these lines, my goal is still to use my experimental measurements to inform future modeling of salt marshes under sea level rise. However, I have shifted my secondary focus away from studying the effects of precipitation change on nitrogen removal processes, and instead have been investigating the effects of precipitation change on silica cycling through plants, sediments, litter, and porewater. Silica cycling in general, and the effects on silica biogeochemistry from climate change in particular, are understudied, but previous work our lab has suggested a connection between drought stress and plant silica uptake (Carey & Fulweiler, 2013).

Location(s) of Research:

The research project takes place within the Cape Cod National Seashore, at the West End marsh in Provincetown, MA.

Key Findings:

My experiment is ongoing, and most data will not be available until this winter when I begin to process the samples I have been collecting. Therefore, I cannot yet say what the experimental manipulations have done to plant growth, sediment characteristics, silica cycling, and porewater nutrient concentrations.

Other types of data are more readily available, including soil moisture and temperature, and greenhouse gas flux data. I have therefore been able to relate carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) flux rates to the moisture and temperature conditions that are most likely to control these rates. Through regression analysis, I have found that so far moisture appears to be very important for CO_2 and N_2O fluxes, but not for CH_4 fluxes. However, I have found that precipitation treatment does somewhat predict CH_4 flux rates, which suggests that a treatment effect other than moisture (for instance, salinity or another variable effected by rainfall) is more important for this gas. Most surprisingly, I have found that this marsh is on average a net sink for CH_4, which is very unusual for wetlands including salt marshes, which are typically small to large sources depending on salinity.

Deliverables/Research Products: (Please list.) *This may include, but is not limited to presentations at the park(s), conferences/meetings attended, interpretive talks, published articles, electronic education products, etc.*

Include the links to any of your research products that are available electronically. If they are print products, please attach them at the end of this report as appendices.

- "Salt Marsh Biogeochemistry in a Changing Climate: The Effects of Extreme Precipitation" Oral presentation, Cape Cod National Seashore Science in the Seashore Symposium, August 28 2014.

- Website describing my research: http://www.fulweilerlab.com/hollie-precipitationpage.html

Additional Funding:
Were you able to use the Fellowship as leverage for securing other research funding? If so, please list the sponsor, program, and the amount of funding.

As described in my 2013 Status Report, I received two other funding awards to support this research. The Friends of the Cape Cod National Seashore awarded me the 2013 Nickerson Conservation Fellowship in the amount of $3000, and Boston University awarded me the 2013 Biogeosciences Research Fellowship Award in the amount of $500. This year, I also applied for the NSF Doctoral Dissertation Improvement Grant to potentially continue this research through 2015 and expand the scope to include an examination of how the total and active microbial community changes in the experimental conditions studied here.

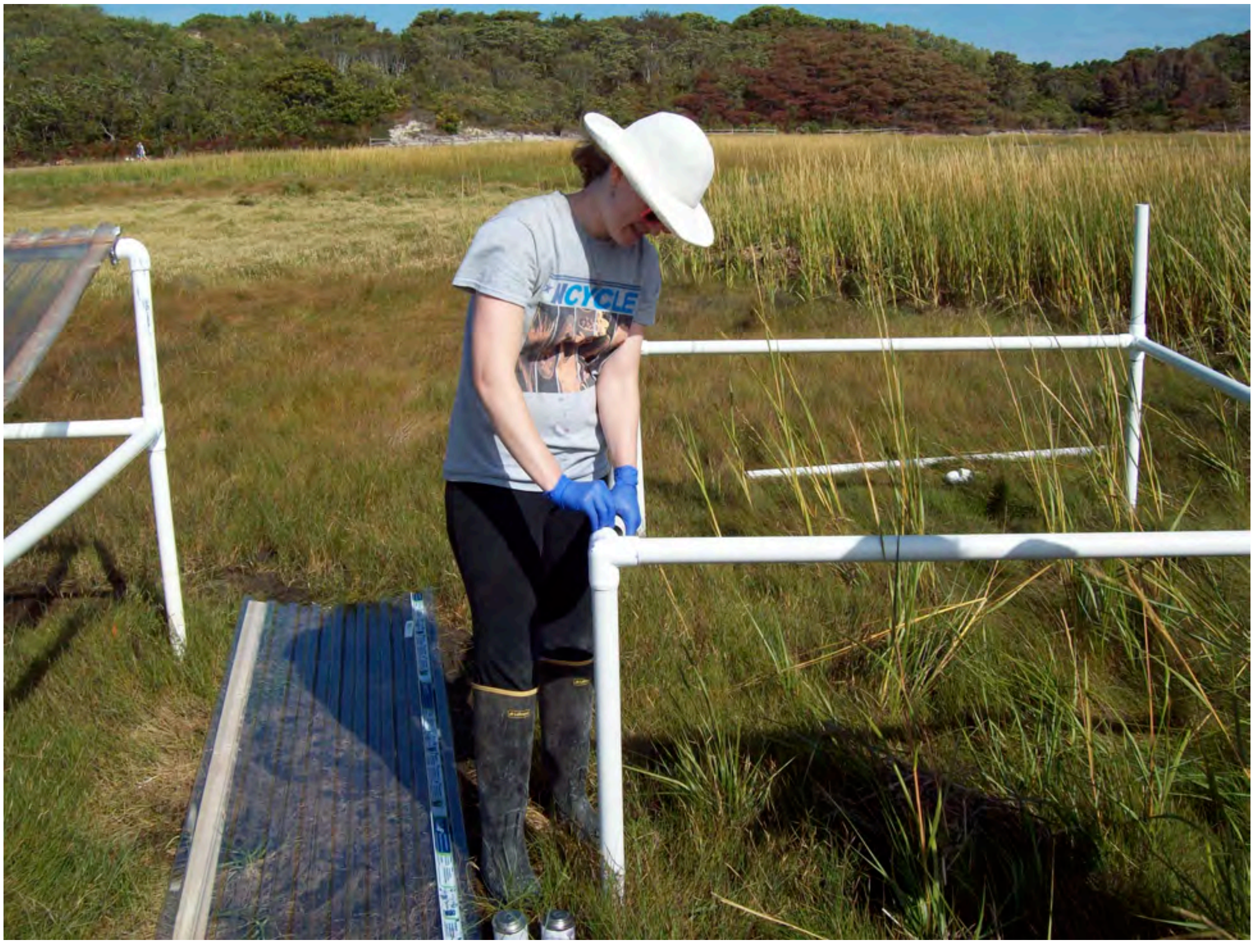
Other:
- *Please include information about additional products, presentations, or outcomes related to this research project that are not otherwise included in this report.*

Boston University's newspaper reported on my research, producing a short video and written article. These are available at http://www.bu.edu/today/2014/the-rainmaker/

- *Please share any anecdotes or stories from your project -- surprising discoveries, interesting happenings in the field, etc. -- that you think would be especially interesting for a general audience.*

Photographs:
Please include 3-5 photographs from your project. We are especially interested in any photos of you doing your research.
** In doing so, you are granting the University of Washington and the National Park Service permission to use your photos in publications (web, electronic, or print) related to the George M. Wright Climate Change Youth Initiative.*


Picture 1: Hollie Emery (fellow) measuring high tides for site selection Fall 2013.



Picture 2: Hollie Emery (fellow) building a rain-blocking structure Spring 2014.

Picture 3: A team of Boston University undergraduate interns assisting with greenhouse gas flux measurements, Summer 2014.

Picture 4: Hollie Emery (fellow) making CO_2 flux measurements in Summer of 2014.

2013 NPS George M. Wright Climate Change Youth Initiative
Fellowship Research Final Report
December 31, 2014

Fellow Name: Louise Farquharson
University: University of Alaska Fairbanks
Start date: September 2013
End date: November 2014 (but extended with separate funds to September 2015)

Brief project summary:
I am assessing the effect of coastal erosion in the Bering Land Bridge National Park (BELA) and preserve in light of the increasing length of ice-free summers. Because coastal erosion occurs during the ice-free period, an increase in its duration is likely to cause changes in coastal processes and erosion rates, resulting in environmental stressors to the BELA coast and near-coast ecosystems.

Research Approach:
Comparison of high-resolution satellite imagery (Worldview2) with historical aerial photographs, using the USGS DSAS protocol, with the addition of erosion and vegetation line as a proxy for coastal change in addition to instantaneous water line.

Location(s) of Research:
Bering Land Bridge National Park and Preserve

Key Findings:

	1950 - 1980	1980-2003	**2003-2013**
Rates (m/yr)			
Mean	-0.21	0.001	-0.86
Max	-11.44	-3.97	-6.49
Min	5.91	7.73	4.46
St.dev.	0.81	0.78	1.23

Modified from Gorokhovich and Leiserowiz 2012

Table 1. Inter-decadal comparison of water line rate of change for key study areas within the Bering Land Bridge National Park and Preserve. Negative values indicate erosion, positive values indicate accretion. First two columns are from Gorokhovich and Leiserowiz 2012, while highlighted yellow column is this study.

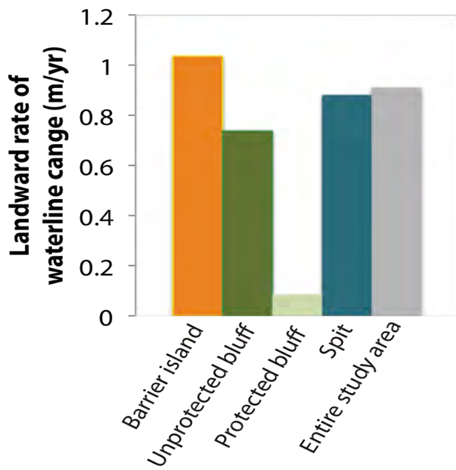


Figure 1. Coastal change coastal geomorphology type. Main findings:
•Barrier island – 1.04 m/yr
•Unprotected bluff – 0.74 m/yr
•Protected bluff – 0.09 m/yr
•Spit – 0.88 m/yr
•Spit feature – typically aggrading – mean change shows eroding
•Barrier islands – highest erosion rates
•Protected bluff lowest erosion rate

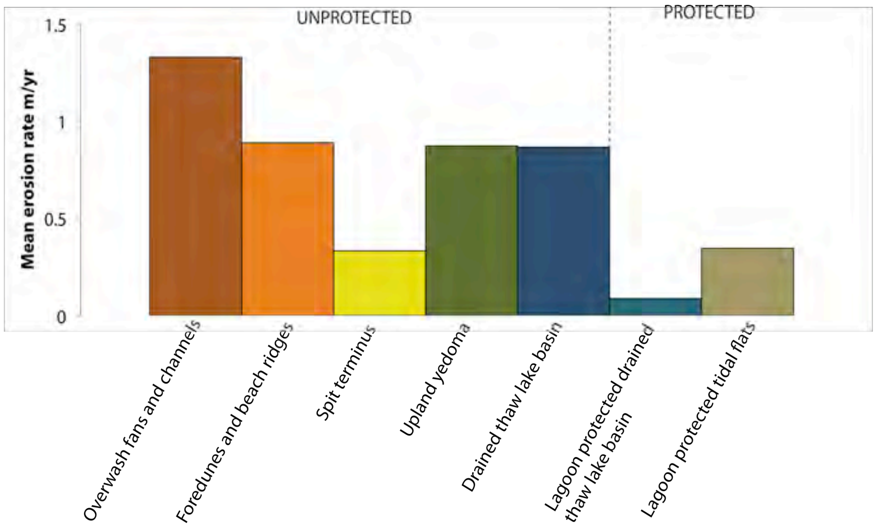


Figure 2. Coastal change by landform type. Unprotected and protected classes refer to whether the coastline is protected by a barrier island system.

•Importance of barrier islands - protected vs unprotected

•Surprisingly little difference between ice rich uplands and ice poor drained lake basin bluffs

•Overwash fans and channels most dynamic

Figure 3.

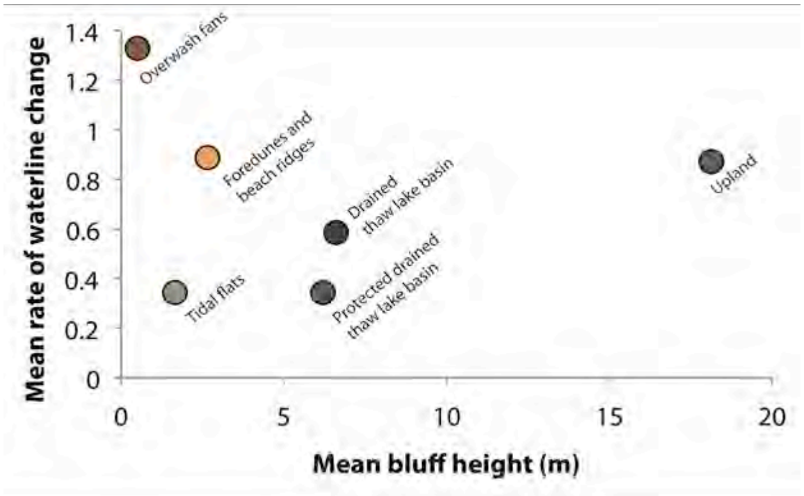


Figure 3. Mean rate of change plotted against mean bluff height for key landform types. Overall erosion rates decrease as bluff heights increase. Upland sites are thought to be outliers due to the presence of massive ice bodies (ice rich permafrost).

Additional data sets:

- Erosion line digitization in 2013 and 2003 imagery
- Error assessment of digitized transects (if water line obscured or unclear, how much error etc.)
- Geomorphological classification of shoreline segments
- Topographic profiles of geomorphological classes
- Digital shoreline analysis for 2003 - 2013, instantaneous water line
- Digital shoreline analysis for 2003 - 2013 erosion line
- Linear projection of next 100 years of erosion (shapefiles, separated by geomorphic class).

Deliverables/Research Products: (Please list.) This may include, but is not limited to presentations at the park(s), conferences/meetings attended, interpretive talks, published articles, electronic education products, etc.

- June 2014, Oral presentation at 4th European Conference on Permafrost, Evora, Portugal, Farquharson, L. M. , Mann, D. H. , Grosse, G. , Jones, B. , Swanson, D.*and Romanovsky, V. E. (2014): Understanding coastal dynamics along a permafrost affected coastline in northwestern Alaska, USA.

- November 2014, invited oral presentation, NPS Climate Change Webinar Series. Farquharson, L.M., Swanson, D.K.*, Mann, D.H., Coastal erosion along a permafrost affected shoreline in NW Alaska.

  *National Park Service mentor

- November 2014. Outreach talks in both Kotzebue and Selawick, Alaska. Two remote communities impacted by changes in coastal dynamics. This was a valuable experience where we both distributed knowledge to coastally affected communities while also hearing about observations of climate change from those living and subsistence fishing in my study area.

Include the links to any of your research products that are available electronically. If they are print products, please attach them at the end of this report as appendices.

- Final products will be compiled once the additional year of research has been completed. Products will include GIS layers of BELA and CAKR waterlines and erosion lines, maximum likelihood classifications of land cover change in key study areas, quantitative landform change analysis, chapter of dissertation (October 2017), final NPS report (January 2018).

Additional Funding:
Were you able to use the Fellowship as leverage for securing other research funding? If so, please list the sponsor, program, and the amount of funding.

- National Park Service: Cooperative agreement (CESU) between NPS and University of Alaska Fairbanks. "Coastal landform change in the NPS Arctic Inventory and Monitoring Network"" $60,036. September 2014 - August 2015.

- Other: Permafrost Young Researchers Network - Early career scientist travel grant $1500 towards attending European Conference on Permafrost

Please include information about additional products, presentations, or outcomes related to this research project that are not otherwise included in this report.

- Coastal monitoring work with the National Park Service Arctic Networks will continue for the next academic year (CESU mentioned above). My original study area will be extended to the entire Bering Land Bridge National Park and the Cape Krusenstern National Monument. Additional imagery has been acquired which will enable me to extend and improve data sets developed of the past year.

Please share any anecdotes or stories from your project -- surprising discoveries, interesting happenings in the field, etc. -- that you think would be especially interesting for a general audience.

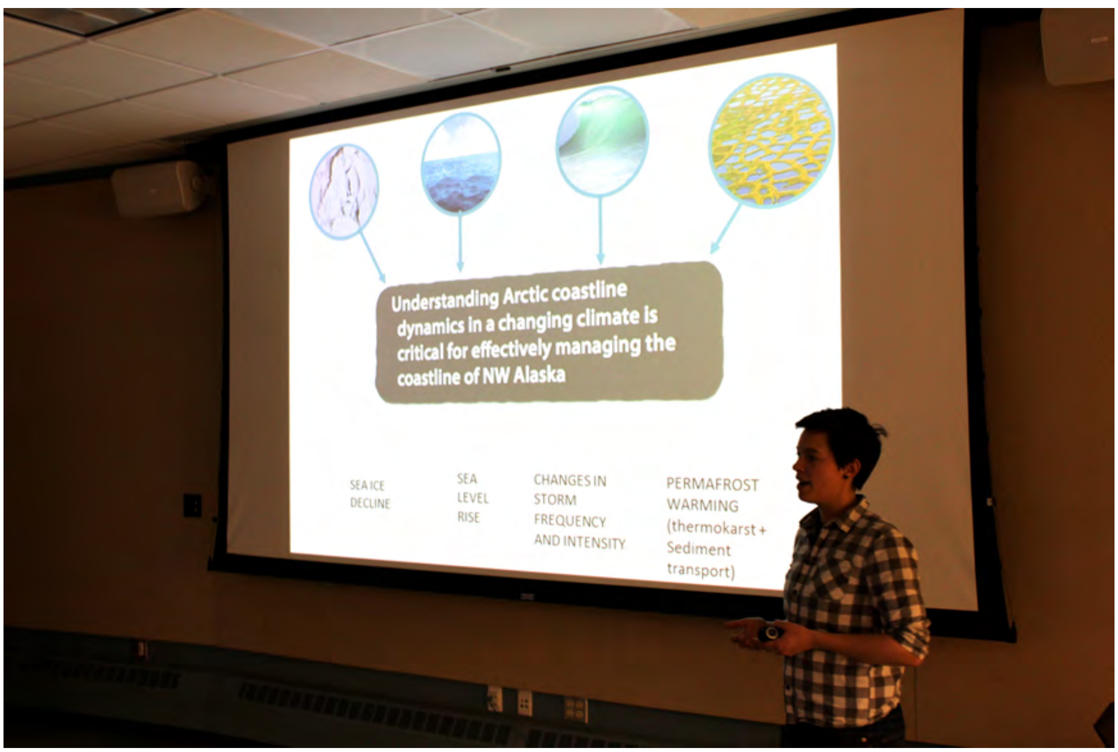
Our results show that erosion rates have picked up in the last 10 years compared to the previous 50. This is likely due to a combination of sea ice decline and increased storminess.

We had very successful outreach talks in both Selawick (turn out of ~ 60 people in a village of 800) and Kotzebue (turn out of around 20 people in a town of 2000). I presented with two other researchers all presenting data on NPS funded climate change projects in the region. Locals were very interested in quantitative data sets on coastal erosion and asked many questions, with a lot of people staying behind after the talk to discuss the data sets further and tell us about their own observations.

Photographs:

Please include 3-5 photographs from your project. We are especially interested in any photos of you doing your research.
In doing so, you are granting the University of Washington and the National Park Service permission to use your photos in publications (web, electronic, or print) related to the George M. Wright Climate Change Youth Initiative.

Presenting CCYI funded project research results in Kotzebue Alaska at the NPS Heritage center.



Presenting CCYI funded project research results in Kotzebue Alaska at the NPS Heritage center.

Discussing the impact of climate change and permafrost degradation with locals in Selawick village, Alaska.

Participating in Kotzebue high school science fair while visiting town to present CCYI funded project talks.

2013 NPS George M. Wright Climate Change Youth Initiative
Fellowship Research Final Report
December 31, 2014

Fellow Name: Victor Garrett
University: South Dakota State University
Start date: June 2013
End date: May 2015

Brief project summary:
To quantify the duration and frequency of beaver pond inundation, and relate these dynamics to observed climate conditions, landscape characteristics, and beaver presence. Then classify the vulnerability of beaver ponds to drought, and evaluate the changes to ecosystem services that would result from a loss of beaver ponds in Voyageurs National Park.

Research Approach:
There were some changes in the original research approach due to my injury in the field (as described in last year's report). This limited the number of measurements that were able to be physically taken on beaver ponds in the field, thus requiring more of a reliance on GIS and aerial photos. All other research approaches are the same is described in the initial proposal.

Location(s) of Research: Voyageurs National Park

Key Findings:
I still need to complete the projected effects of climate on the beaver wetlands, and this will be accomplished within the next couple of months. Most of the work thus far has been focusses on assessing the stability of the beaver ponds in the park and developing metrics to quantify the stability. These metric will be used to assess the vulnerability of the ponds to changes in climate.

Deliverables/Research Products: (Please list.)

Garrett, V.W. and C.A. Johnston. 2014. Climate Influences on Beaver Pond Stability at Voyageurs National Park (poster). The Wildlife Society National Conference, Pittsburgh, PA. 25-30 October.

Garrett, V.W. and C.A. Johnston. 2014. Plumbing the Landscape: Beavers Optimize Dam Sites (poster). CUAHSI Third Biennial Meeting on Water Science and Engineering, Shepherdstown, WV. 28-30 July.

Garrett, V.W. and C.A. Johnston. 2014. Watershed Characteristics Influence Beaver Pond Establishment and Longevity. Joint Aquatic Sciences Meeting, Portland, OR. 18-23 May.

Additional Funding:
Society of Wetland Scientists (North Central Chapter) - $750 research grant
Society of Wetland Scientists (North Central Chapter) - $1000 travel grant

Other:

N/A

Photographs:

2013 NPS George M. Wright Climate Change Youth Initiative
Fellowship Research Final Report
December 31, 2014

Fellow Name: Scarlett Kettwich
University: University of Hawaii at Hilo
Start date: June 2013
End date: August 2014

Fellow Signature **NPS Sponsor Signature**

Brief project summary: Tropical montane cloud forests are among the most vulnerable ecosystems to climate change worldwide. Due to dependence on regular cloud immersion, deforestation, fragmentation and anthropogenic disturbances, a doubling of atmospheric CO_2 will produce a climatic altitude shift of hundreds of meters for these mountain ecotones. Current estimates predict that by 2100, cloud forests on summits will be expelled into extinction and replaced by lower altitude ecosystems. In the face of Hawaii's predicted drying climate, loss of these ecosystems due to changes in moisture balance through decreased relative humidity and cloud cover, elevated lifting and condensation level, and lowered trade wind inversion may have drastic effects on watershed yield and threaten hydrological ecosystem services. Current research suggests that tropical vegetation may be lagging in response to changing climate, data sets are too few to detect change, or these systems are resilient.

Epiphytes favor canopy suspension and thus hugely depend on the atmosphere for required moisture and nutrients. They also indicate plant-atmosphere interactions of cloud forests. Changes in the epiphyte community may provide early indications of Hawaii forest's vulnerability to climate change. My main objective is to understand how these sensitive plants interact with the atmosphere. I am establishing a baseline from which changes in the epiphyte community can be monitored as a near-term indicator of climate change by:

1) Investigating patterns of epiphyte abundance and species composition across an elevation and precipitation gradient on windward Hawaii Island.
2) Using physiological measurements to investigate the relative importance of fog in epiphyte-atmosphere interactions.

Research Approach:
No significant changes.

Forest sites are dominated by Ohia Lehua (*Metrosideros polymorpha*) across broad geographic and climatological ranges, thus allowing examination of epiphytes on this single host. The rainfall gradient keeps elevation constant at 1000 - 1200m, while varying rainfall between 2,400 and 6,400 mm/year. The elevation gradient keeps rainfall constant at 3000mm/year, and varies elevation between 200 and 1750 m. At each site we control microclimatic differences by choosing trees that are 30-50cm DBH with no branches >5cm DBH below 5m. All candidate trees have no neighbor trees and are not leaning less than 80°. Each tree trunk is divided into half-meter intervals from ground level up to 5m**.** In each increment, the presence of species of all trunk epiphytes is recorded and binoculars assist in identifying epiphytes above 5m. Results are compiled to produce a frequency measurement and Analyzed using an ANOVA.

Location(s) of Research:

Study Sites:

• HAVO hosts five ideal sites in *Metrosideros* dominated forest for the gradient portion of this investigation:
- Along Hilina Pali Road at 1000m elevation and 2000mm rainfall.
- Puu Puai Forest area at 1000m elevation and 3000mm rainfall.
- Olaa Forest Reserve (eastern corner) at 1000m elevation and 3000mm rainfall.
- North of Naulu Trail at 800m elevation and 3000mm rainfall.
- Olaa Tract North of Wright Road Bend at 1200m elevation and 3000mm rainfall.

• HAVO hosts one of the two ideal sites for the stable isotope portion of this investigation:
- Thurston Lava Tube forest area at 1100m elevation and 3000mm rainfall. This site is comparable in both forest structure and annual rainfall to a second site outside the national park. But, this site has a relatively static or stationary fog input. (The second site for the stable isotope portion of this investigation has a vectored, moving, wind driven fog input.)

• Other sites nearby NPS lands include:
- Olaa Forest Reserve at 1000m elevation and 4000mm rainfall.
- Olaa Forest Reserve at 1000m elevation and 5000mm rainfall.
- Upper Waiakea Forest Reserve at 1000m elevation and 6400mm rainfall.
- Upper Waiakea Forest Reserve at 1400m elevation and 3000mm rainfall.

• Additional Study sites outside HAVO were used to establish a rainfall and elevation gradient. Maps of each gradient are included in Appendix 1.

Key Findings:

Results across the Elevation Gradient indicate that the lower elevations have both higher Mean Epiphyte Frequency and Mean Epiphyte Diversity. This is likely driven by *Freycinetia arborea*, a common low elevation vine. Results across the Rainfall Gradient indicate that Mean Epiphyte Frequency and Mean Species Diversity increased from low to high rainfall, suggesting that moisture is an important determinant of where an epiphyte grows (Figures 3 and 4 respectively). Site (d) was lower in both Mean Epiphyte Frequency and Mean Species Diversity than sites (b) and (c), which may be due to limitations in the rainfall estimate at this remote site. Based on vegetation analyses at these sites, rainfall may be slightly lower at site (b) and slightly higher at (c). Also, current rainfall estimates do not account for fog, and site (b) may have a larger input of fog than Sites (c) and (d). A climate station with rain and fog gauges was installed near site (b) to help elucidate these differences, and this data will be included with completion of my Master's Thesis in spring 2015 and a report given to HAVO.

Because Mean Species Diversity increased from low to high rainfall, it may suggest that an increase in moisture increases niche space for various epiphyte species. Because Mean Filmy Fern Frequency and Mean Moss Frequency both showed similar increasing trends with similar dips after sites (b) and (e), this may indicate that Filmy Ferns require moss substrate, or that moss substrate helps create arboreal soil for Filmy Fern development. Data is still being analyzed and will help sift out these relationships as well as potential critical thresholds.

Overall, epiphyte communities showed much finer scale responses to climate variation when compared with structurally dominant vegetation. The precipitation gradient exhibits a clear increase in abundance of all epiphyte groups and a definable increase in diversity with increasing rainfall. Results across the elevation gradient show a higher abundance of filmy ferns above the lifting condensation level (about 600m) where fog incidence is highest and PET is lowest, as well as a marked difference in composition, whereby larger species dominate lower elevations where temperatures are greater.

Results suggest that fog is an important determinant of how ecophysiological characteristics of epiphytes respond to the environments they inhabit. Future research should investigate the input of greater fog due to wind. I will continue to further evaluate these results with respect to fine-scale climate models based on statistical downsampling of GCM's. Small, short-lived species, especially filmy ferns, are likely to exhibit the most rapid response to Hawaii's changing climate wheras larger, longer lived species are likely to respond more slowly.

Deliverables/Research Products: (Please list.) This may include, but is not limited to presentations at the park(s), conferences/meetings attended, interpretive talks, published articles, electronic education products, etc.

1) Although work for this portion of the project is complete, I am still working on my overall Masters work and will be finished in Spring 2015. At that time, I will provide a copy of my Masters Thesis directly to Hawaii Volcanoes National Park. A presentation at Hawaii Volcanoes National Park will be scheduled for Spring 2015, and will coincide with termination of my Master's work.

2) Presentations/Conferences attended:
I. Poster Presentation: American Geophysical Union, San Francisco, CA. Epiphytes as an Indicator of Climate Change in Hawaii - Dec 10th, 2013.
II. Oral Presentation: 25th Annual Hawaii Ecosystem Meeting hosted by Dr. Peter Vitousek at the University of Hawaii at Hilo. Epiphytes as an Indicator of Climate Change in Hawaii - July 9th, 2013.

3) Interpretive talks:
Malama Pono Environmental Outreach Program at Pahoa High School, Pahoa HI. We produced a curriculum that educates students about epiphytes as indicators of climate change for the Pahoa High 10th grade inclusion Biology class. The curriculum includes multiple in-class visits over a single semester and two field trips. The curriculum also aims

to connect Pahoa High students with opportunities for higher education at UH Hilo. We wrote the curriculum such that other teachers or programs may use the lessons for themselves in the future. We also created a Hawaii Climate Change Challenge board game. Hard copies of this game were used in class visits and distributed to teachers and other programs for further use. This learning tool was developed to reach a variety of age levels (12 and up) to teach about the impacts of climate change in Hawaii, as well as personal actions that help mitigate climate change. (Board game layout, cards, and template figurines attached in Appendix 2.)

Include the links to any of your research products that are available electronically. If they are print products, please attach them at the end of this report as appendices.

- Appendix 1: Figures
- Appendix 2: Climate Change and Watershed Board Game – Outreach Material

Additional Funding:
Were you able to use the Fellowship as leverage for securing other research funding? If so, please list the sponsor, program, and the amount of funding.

Yes – I also obtained $70,000 from the Pacific Islands Climate Change Center and $2000 from the University of Hawaii Diversity and Equity Initiative**.**

Other:

- Please include information about additional products, presentations, or outcomes related to this research project that are not otherwise included in this report.

With the conglomerate of funding, this research project not only investigated the natural environment but also helped a variety of people. Overall, the entire project supplied one Part time job for the entire duration of the project, jobs for two summer field assistants during the Summer of 2013 as well as one part time Outreach Assistant for 9 months from 2013 – 2014.

- Please share any anecdotes or stories from your project -- surprising discoveries, interesting happenings in the field, etc. -- that you think would be especially interesting for a general audience.

One surprising insight stemmed from the discovery that Mean Species Diversity increased from low to high rainfall, and may suggest that an increase in moisture increases niche space for various epiphyte species. Even in wet tropical rainforest, where water is typically understood to not be a limiting resource, small moisture differences may drive the adaptive radiation of these epiphytic plants. For example, in field observation, we noticed that different species of the genus *Adenophorous* grow in specific areas of the forest canopy that collect different kinds of rainfall. For example, *Adenophorous hymenophylloides* grows was observed mostly in areas of the forest that collect dripping moisture, such as in under-hangs of branches. In contrast, *Adenophorous tripinnatifidus* was observed mostly in areas that likely collect horizontally moving moisture, such as sticking out on the trunks of trees. Future research could elucidate these differences with DNA testing and stable isotopes may be able to separate the different water sources and trace that source through the plant. Although other species such as finches are typically among the most famous examples of adaptive radiation, the genus *Adenophorous* is a great example of adaptive radiation among ferns.

Photographs:
Please include 3-5 photographs from your project. We are especially interested in any photos of you doing your research.
** In doing so, you are granting the University of Washington and the National Park Service permission to use your photos in publications (web, electronic, or print) related to the George M. Wright Climate Change Youth Initiative.*


Project Intern


Downloading Data from Climate Station

Downloading Data from Climate Station

Appendix 1: Figures

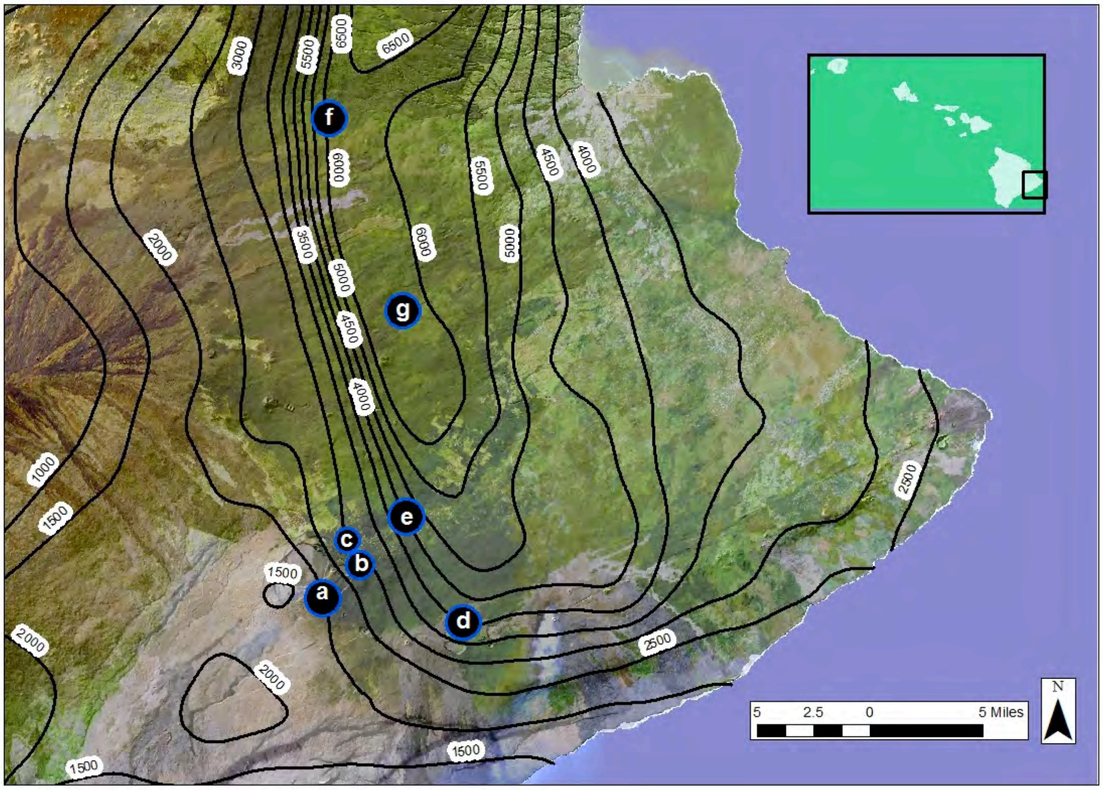


Figure 1: Rainfall Gradient

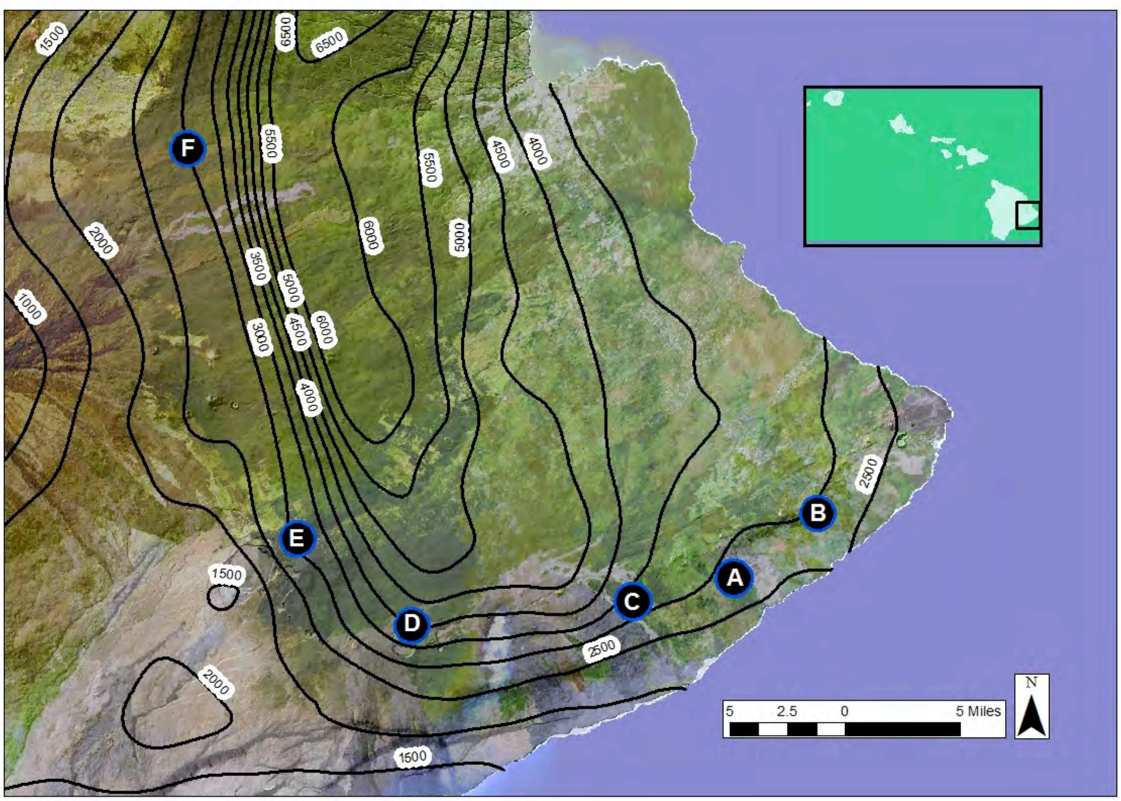


Figure 2: Elevation Gradient.

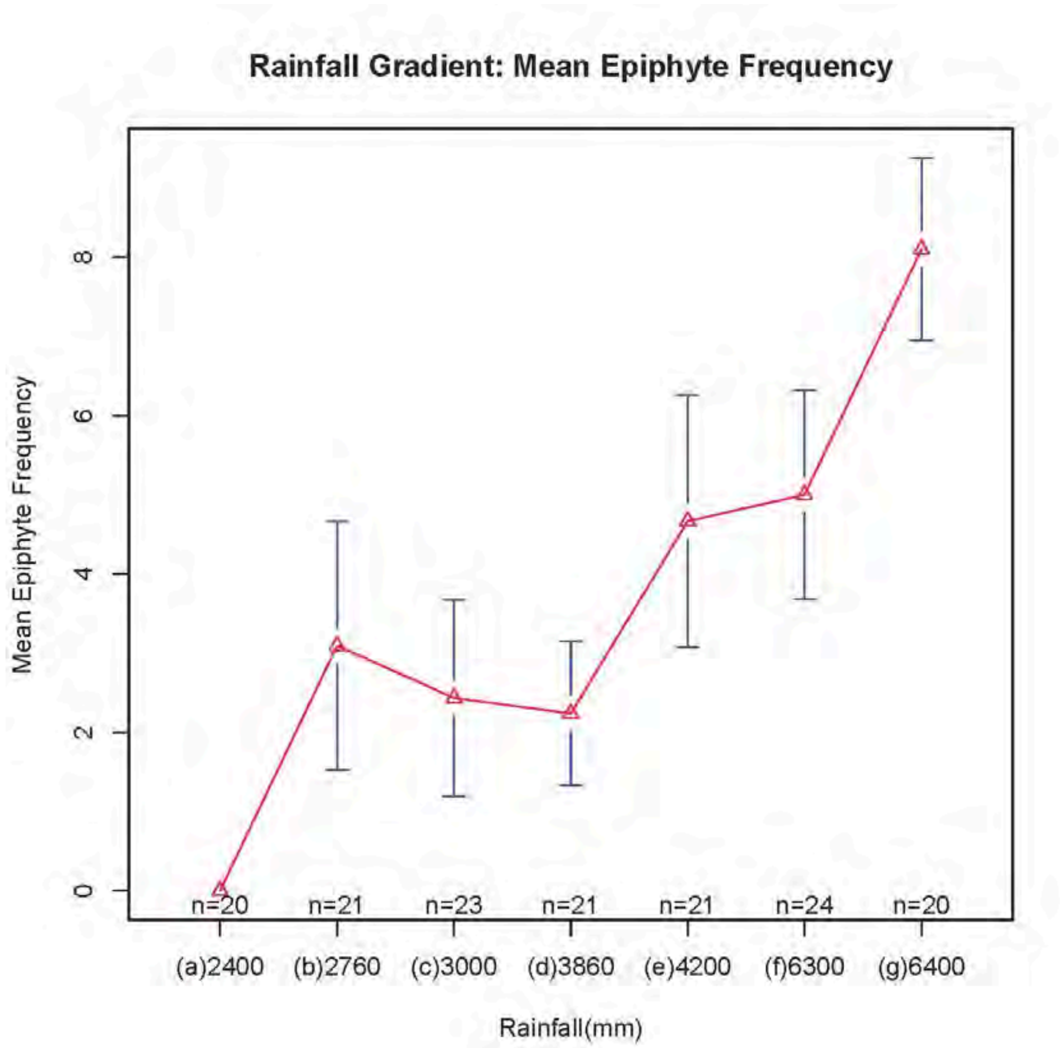


Figure 3: Mean Epiphyte Frequency (grouping excludes filmy ferns) low to high rainfall.

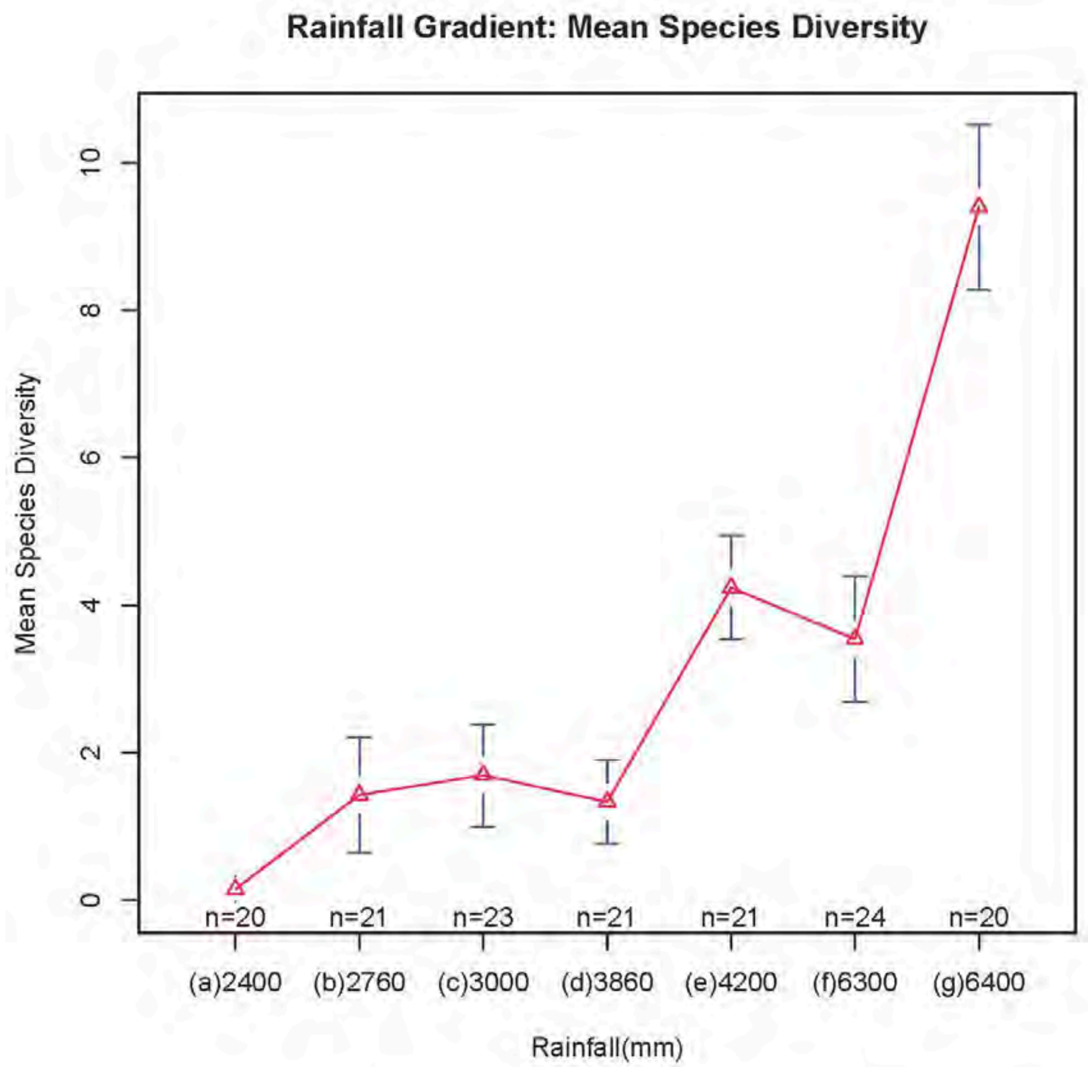


Figure 4: Mean Species Diversity from low to high rainfall.

Appendix 2: Climate Change Outreach – Board Game

Hawaiian Watershed Adventure

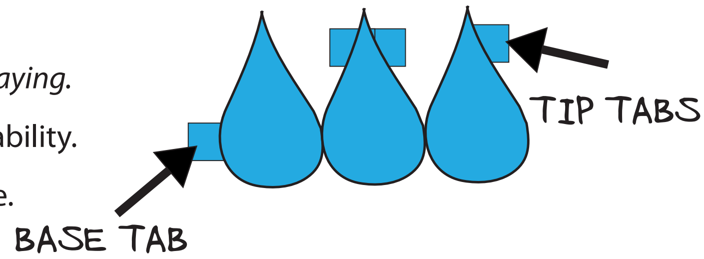
GAME PREPARATION

1. Print board game (20 x 30 inches), 1 per 5 students.

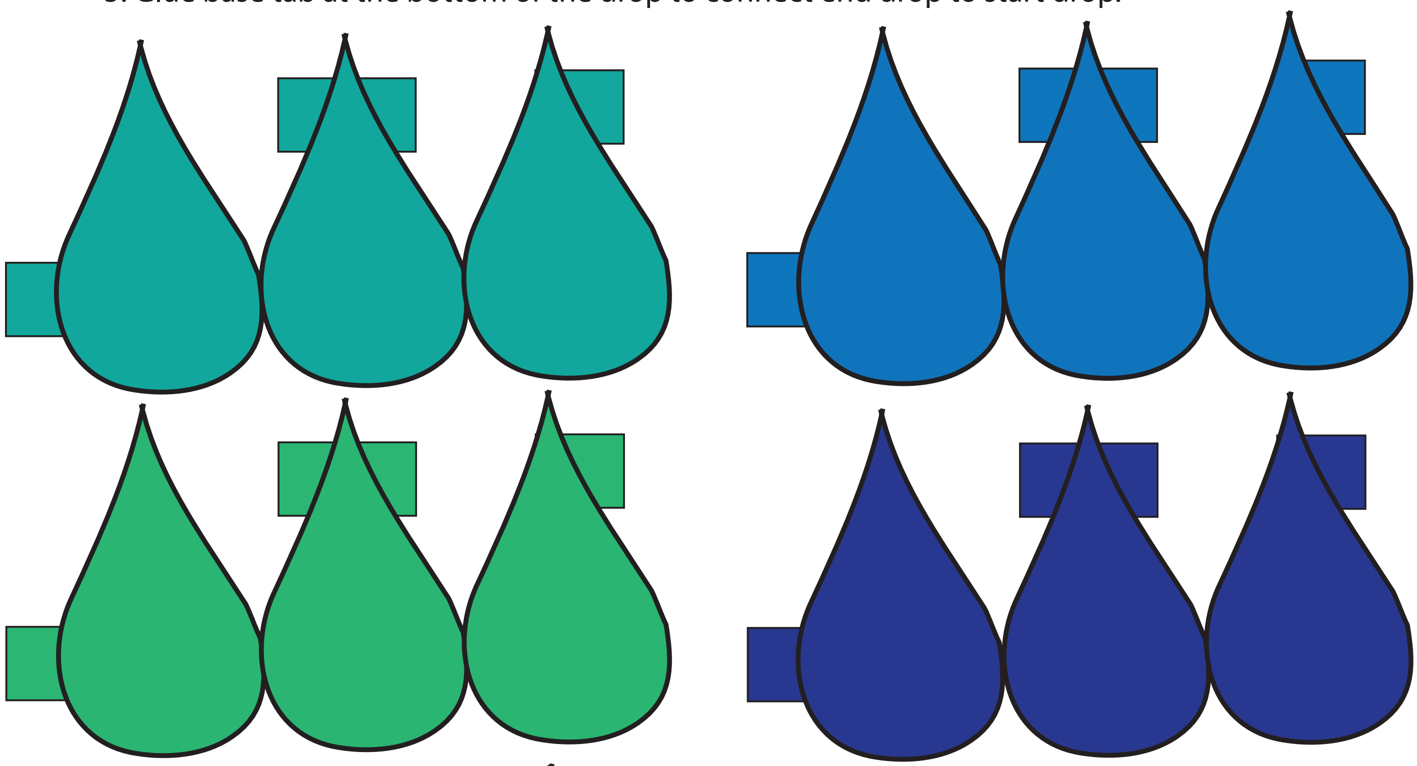
2. Print game card double sided, 1 set per game board. One side of card will have the game text and a photo and the other side will be blue with the game title and a leaf. Cut game cards out.

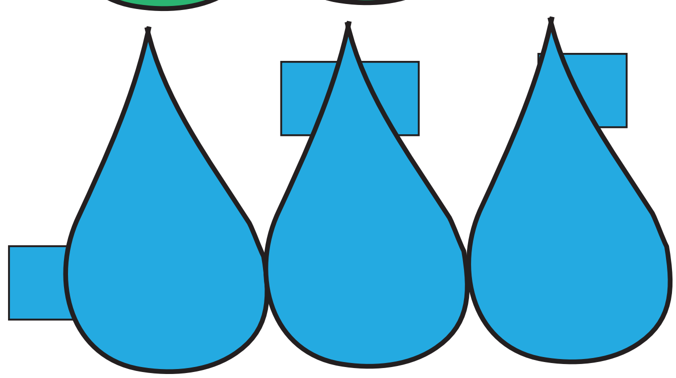
3. Print and cut out game pieces, 1 set per game board.

**Game pieces should be assembled by an adult prior to playing.*



1. Cut out game pieces below. Laminate for durability.
2. Fold all tabs in (away from front of game piece.
3. Fold raindrops in a triangle-like shape.
4. Using a hot glue gun, glue tip tabs at drop tips first so points meet at a single point like a pyramid.
5. Glue base tab at the bottom of the drop to connect end drop to start drop.





Distributed by the State of Hawai'i, Department of Land and Natural Resources, Division of Land and Natural Resources, Division of Forestry and Wildlife, Hawai'i Island Natural Area Reserves System.

GAME RULES

1. Have each player choose a game piece and place it at the start on the game board.

2. To determine the order of players, have each player roll the die. The player with the highest number will go first. The players with the next highest numbers will follow.

3. Each player rolls the die in turn, and move the game piece the number of spaces indicated by the die. If the player lands on a "Leaf with water drop" space, the player must pick up a card, read it aloud, show the photo on the card to the other players, and follow the instructions on the card.

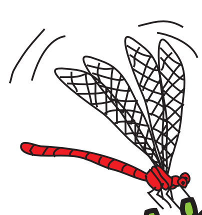
4. If the player lands on:

   Waterfall: The waterfall allows the player to skip a set of spaces. The player will end at the bottom of the waterfall and remain there until their next turn.

   Erosion Zone: The erosion zone skips the player's next turn. Erosion happens when soil is not anchored by the roots of plants washes away with rain.

   Leaf Landing: Allows the player to foll again and play the second square landed on. In a watershed, leaves slow rain drops down, preventing them from hitting the ground with impact and causing soil to run off the landscape.

5. The player only plays the first square landed on. If the first space landed on instructs the player to move again, the player will move but not play the second space landed on unless the second space is a leaf "Leaf Landing: Roll Again" space, in this event, the player will roll again and not play the next space (3rd space) landed on.

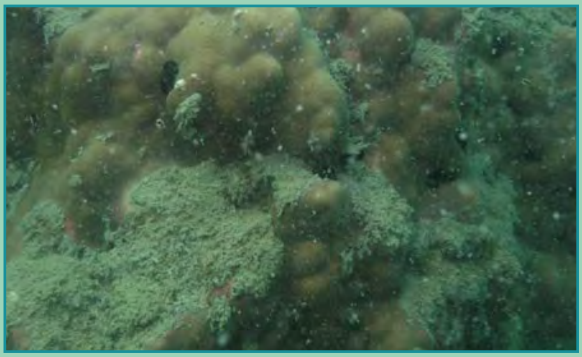


Leaves, branches and understory plants intercept rain before it reaches the ground. This prevents rain drops from hitting the ground with impact and washing the soil away.

Move 3 spaces forward.

An abundance of mosses growing in the rain forests of the Pu'u Maka'ala absorbs rain as it falls. Saturated mosses slowly release water into the aquifer long after the rain has fallen.

Move 2 spaces forward.



Cattle graze the forests located on the coastal slopes of Kohala. Over time the forest disappears and there are no longer any roots to hold the soil in place. With every rain, soil washes into the ocean and smothers the coral reef below.

Move 3 spaces back.

The forest provides leaf surfaces for water vapor to condense on. The forest collects water from passing clouds, drips it down to the ground and eventually into the aquifer. You have more water for drinking!

Move 2 spaces forward.

Hawaiian Watershed Adventure

Hawaiian Watershed Adventure

Hawaiian Watershed Adventure

Hawaiian Watershed Adventure

Photo by: Jack Jeffrey

Protecting our watersheds also protects all the spectacular organisms that live there.

Move 1 space forward.

TEAM PLAY

Fresh water is a precious resource that all people need. All players who can name a way that they use water moves 1 space forward. Answers must be different among players.

Photo by: Jack Jeffrey

Feral pigs root, trample, and eat the plants in the forest understory. Over time the forest disappears and can no longer collect or hold water. Less water is added to the aquifer.

Move 3 spaces back.

Pollution is a negative change in the quality of water, making it non-usable. Chemicals improperly disposed of washes into the aquifer and contaminates our source of fresh water.

Move 3 spaces back.

Hawaiian Watershed Adventure

Hawaiian Watershed Adventure

Hawaiian Watershed Adventure

Hawaiian Watershed Adventure

The roots of trees and understory plants hold the soil firmly in place, Even with heavy rains, no soil erosion takes place.

Move 2 spaces forward.

Photo by: Robert Stephens

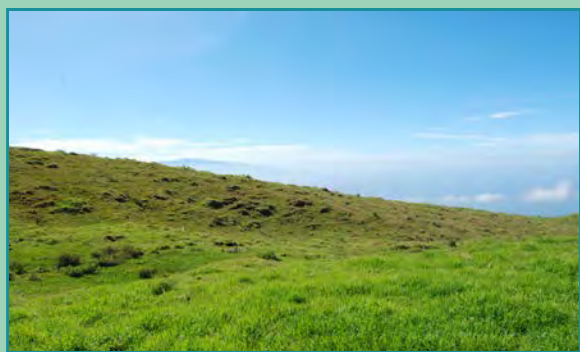
A herd of sheep move across the forested slopes of Mauna kea eating the tender māmane and naio seedlings that sprouted last winter. Over time, the adult trees die and there are no new trees to take their place. The forest disappears, and no longer collects and holds water.

Move 3 spaces back.

Photo by: Robert Stephens

The forests of Mauna kea have been destroyed by browsing sheep. There are no longer any roots to hold the soil in place, With every rain soil is washed away.

Move 2 spaces back.



A koa forest is logged for wood. There are no longer any trees to collect water from passing clouds. Less water is added to the aquifer.

Move 2 spaces back.

Hawaiian Watershed Adventure

Hawaiian Watershed Adventure

Hawaiian Watershed Adventure

Hawaiian Watershed Adventure

Lichens are an two-part organism consisting of a fungus and an algae. Lichens in a forest help to slow rain as it falls to the ground. Lichens also absorb rain fall and slowly release it into the aquifer.

Move 1 space forward.

Fences protect forests from ungulate damage (damage from hoofed animals such as sheep, pigs, goats and deer). These protected forests are large contributors of water to our aquifers.

Move 3 spaces forward.

Greenhouse specialists grow plants to reforest areas where the forest has been removed or disturbed.

Move 1 space forward.

The beautiful forests of Kohala continues to thrive with the care of natural resource managers and the surrounding community.

Move 3 spaces forward.

Hawaiian Watershed Adventure

Hawaiian Watershed Adventure

Hawaiian Watershed Adventure

Hawaiian Watershed Adventure

Community members volunteer to plant Koa trees at Keahou—a once beautiful and thriving forest that has been denuded by cattle ranching over the last 200 years.

Move 4 spaces forward.

Photo by: Robert Stephens

A herd of hungry sheep destroy a large area of high elevation forests in a very short time. With just a few trees remaining the land becomes dry and less water is delivered to the aquifer.

Move 2 spaces back.

The community helps to restore the goat decimated forest of Ka'ūpūlehu. Over time plants start to sprout on their own, and the forest begins to heal.

Move 3 spaces forward.

Photo by: Jack Jeffrey

Many community members volunteer to plant koa trees in effort to restore Hakalau forest. Over time these trees mature and provide habitat for native birds.

Move 3 spaces forward.

Hawaiian Watershed
Adventure

Hawaiian Watershed
Adventure

Hawaiian Watershed
Adventure

Hawaiian Watershed
Adventure

Ferns in the understory are a sign of a healthy forest and a healthy watershed!

Move 1 space forward.

Hawai'i's youth take part in planting native trees to restore the watersheds of Hawai'i.

Move 2 spaces forward.

After 200 years of browsing by goats and cattle, the forests of Kaho'olawe have disappeared. With each rain soil washes into the reefs below. In some areas up to 12 feet of soil have washed into the ocean.

Move 4 spaces back.

Large tracts of forest are cut down to make room for development. This increases the surfaces that prevent water from soaking into the ground. Areas such as parking lots, roads and rooftops reduces ground water levels.

Move 3 spaces back.

Hawaiian Watershed Adventure

Hawaiian Watershed Adventure

Hawaiian Watershed Adventure

Hawaiian Watershed Adventure

As a watershed becomes developed, trees, shrubs, and other plants are replaced by surfaces such as parking lots that do not allow water to soak into the ground. This results in lower ground water levels.

Move 3 spaces back.

Polluted storm water carries heavy metals and other chemicals into streams and other bodies of water. This contaminates our ground water and the environment.

Move 2 spaces back.

Hawaiian forests are highly efficient at capturing and retaining water. They have a multi-layered structure of canopy trees, understory plants, ferns, and mosses which act as a giant sponge. These forests absorb water and allows it to slowly travel to the aquifer.

Move 1 space forward.

The tall, closed forest canopy provides shade that results in less water loss to evaporation and transpiration.

Move 1 spaces forward.

Hawaiian Watershed Adventure

Hawaiian Watershed Adventure

Hawaiian Watershed Adventure

Hawaiian Watershed Adventure

Photo by: Jack Jeffrey

When native forests are damaged and eroded, opportunistic non-native plants invade. While these new plants can hold the soil and prevent further erosion, the new structure it creates is typically simple and not as effective as native forests at capturing and retaining water.

Move 2 spaces back.

Community members remove large amounts of invasive weed species that harm our watershed areas.

Move 1 space forward.

Hawai'i's communities conserve water by not letting their water run and shortening their showers.

Move 3 spaces forward.

Fixing pipe and faucet leaks around your house is a good way to conserve water.

Move 1 space forward.

Hawaiian Watershed Adventure

Hawaiian Watershed Adventure

Hawaiian Watershed Adventure

Hawaiian Watershed Adventure

A Big Island Family plants trees around their house to prevent the soil from eroding into the nearby bay.

Move 2 spaces forward.

The moss covered trees of Kohala collects water from rain and passing clouds which slowly drip and percolate into the aquifer. This increases ground water levels.

Move 2 spaces forward.

The forests of Kohala collects moisture from passing clouds. The water collected slowly enters the aquifer and provides fresh water for the Island of Hawai'i.

Move 2 spaces forward.

A rain storm hits Hilo town. Because Hilo has been developed with parking lots, buildings, and paved over in roads the rain water moves above ground and picks up chemicals as it washes into Hilo Bay.

Move 1 space back.

Hawaiian Watershed Adventure

Hawaiian Watershed Adventure

Hawaiian Watershed Adventure

Hawaiian Watershed Adventure

The forest has been damaged by non-native invasive plants and animals. The once closed canopy is now open due to less trees. Each rain evaporates in the harsh sun before it can soak into the aquifer. There is less drinking water available.

Move 2 spaces back.

Students in the ʻImi pono no ka ʻĀina environmental education program learn about the plants in the watershed that contribute to water collection.

Move 2 spaces forward.

Conversion from forest to pasture land and many years of cattle grazing has greatly reduced the forests of Hawaiʻi. With fewer forested areas, less water is captured, and thus less water in the aquifer.

Move 2 spaces back.

As clouds move past this healthy native forest water droplets collect on leaves and gently drip to the ground. The water collected by this forest makes its way to the aquifer, contributing higher ground water levels.

Move 3 spaces forward.

Hawaiian Watershed Adventure

Hawaiian Watershed Adventure

Hawaiian Watershed Adventure

Hawaiian Watershed Adventure

As the soil of a disturbed forest erodes, weed species begin to grow in place of the natives that used to grow there.

Move 2 spaces back.

TEAM PLAY

Fresh water is a precious resource that all people need. All players who can name one way that they can save water moves 1 space forward. Answers must be different among players.

Leaving the water running while you brush your teeth wastes up to 8 gallons of water! If you turn off the faucet while brushing you'll save up to 200 gallons of water a month!

Move 1 space forward.

Watering your lawn or garden while it is sunny wastes water because much of it evaporates in the heat. Instead you water your lawn early in the morning or late evening while it is cool and save lots of water

Move 2 spaces forward.

Hawaiian Watershed Adventure

Hawaiian Watershed Adventure

Hawaiian Watershed Adventure

Hawaiian Watershed Adventure

A leaky toilet is like flushing the toilet 50 times a day for no reason! Your toilet has a leak and your fix it. This saves you about 200 gallons of water every day.

Move 1 space forward.

You decide to take a shower rather than taking your bath in a tub. Filling up a bath tub takes 70 gallons of water while taking a shower only uses 10–25 gallons. You save even more water by keeping your shower to 10 minutes.

Move 2 spaces forward.

A school group plants over 200 trees in effort to reforest an area that has been converted into pasture. In the future it will grow into a forest that will once again collect and store water.

Move 2 spaces forward.

The community helps to plant native saplings in a fence-protected area. These saplings will eventually grow into a forest that will contribute fresh water to our aquifers.

Move 2 spaces forward.

Hawaiian Watershed Adventure

Hawaiian Watershed Adventure

Hawaiian Watershed Adventure

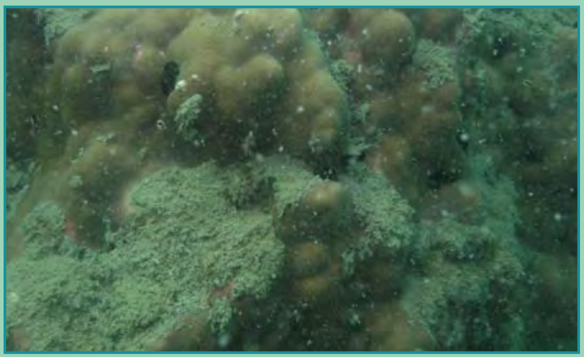
Hawaiian Watershed Adventure

Leaves, branches and understory plants intercept rain before it reaches the ground. This prevents rain drops from hitting the ground with impact and eroding the soil away.

Move 3 spaces forward.

An abundance of mosses growing in the rain forests of the Pu'u Maka'ala absorbs rain as it falls. Saturated mosses slowly release water into the aquifer long after the rain had fallen.

Move 2 spaces forward.



Cattle graze the forests located on the coastal slopes of Kohala. Over time the forest disappears and there are no longer any roots to hold the soil in place. With every rain, soil washes into the ocean and smothers the coral reef below.

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The forest provides leaf surfaces for water vapor to condense on. The forest collects water from passing clouds and drips it down to the ground and eventually into the aquifer. You have more water for drinking!

Move 2 spaces forward.

Hawaiian Watershed
Adventure

Hawaiian Watershed
Adventure

Hawaiian Watershed
Adventure

Hawaiian Watershed
Adventure

Hawaiian Watershed Adventure
Department of Land and Natural Resources
State of Hawaii
Hawaii Island
NARS
NATURAL AREA RESERVES SYSTEM
Start Here
EROSION ZONE
SKIP YOUR NEXT TURN
LEAF LANDING
ROLL AGAIN
LEAF LANDING
ROLL AGAIN
EVAPORATED!
Remain here until you roll a "5"
3 ROLLS PER TURN
LEAF LANDING
ROLL AGAIN
EROSION ZONE
SKIP YOUR NEXT TURN
EROSION ZONE
SKIP YOUR NEXT TURN
The Race for Fresh Water
LEAF LANDING
ROLL AGAIN
LEAF LANDING
ROLL AGAIN
EROSION ZONE
SKIP YOUR NEXT TURN
Place Cards Here
EROSION ZONE
SKIP YOUR NEXT TURN
Aquifer
A geologic formation of sand, soil, silt, and gravel where groundwater is stored.

2013 NPS George M. Wright Climate Change Youth Initiative
Fellowship Research Final Report
December 31, 2014

Fellow Name: Amanda Kissel
University: Simon Fraser University
Start date: May 13, 2013
End date: December 31, 2014

Brief project summary:
My project focuses on adding up the stage-specific effects of climate change on montane amphibians. Specifically, I am looking at how changes in hydrology expected with climate change will affect the larval amphibian stage, and how climate affects annual adult survival, body condition, and summer foraging activity. I will use this information to build a population model to explore how climate change will influence different life-history stages, and how these stage-specific effects contribute to population stability.

Research Approach:
Please describe any significant changes to the original questions, hypotheses, or approach you used in your research.

I proposed to monitor wholesale larval mortality of Cascades frogs (*Rana cascadae*) in several regions of Olympic National Park, Mt. Rainier National Park, and North Cascades National Park. Additionally, I had proposed to monitor adult body condition of a population of Cascades frogs in Olympic National Park, as part of an ongoing, long-term demographic study in the region. I will use these data in a population matrix model, to forecast the extinction risk of Cascades frogs into the future, using different climate change scenarios.

I have successfully accomplished our field objectives (monitoring larval development and mortality) in Mt. Rainier and Olympic National Parks, however in the 2 years of our study, we were unable to locate *R. cascadae* larvae in North Cascades National Park, despite numerous surveys based on historical records and Park knowledge of the species.

In addition to these goals, we added a component in 2014 in which we used model frogs to measure temperature and desiccation rates of the species throughout the summer. We will use these data to determine the duration (if any) that temperatures are above the thermal optima for the species (Sinervo 2010).

Location(s) of Research:

- Mt. Rainier National Park: Spray Park, and Palisades region
- Olympic National Park: 7 Lakes Basin, Potholes region, and Upper Lena lake region

- North Cascades National Park: Big Beaver meadow, Dagger Lake & surrounding areas, Twisp pass, Stiletto lake, Kettling lake and surrounding areas.

Key Findings:
Although data collection is complete, data analysis is ongoing, and thus many of the key findings are not yet available. Thus far, we have found that *R. cascadae* larvae are susceptible to mortality due to pond-drying in most of the regions that we surveyed. In both years of the study, ponds dried before metamorphosis occurred in all regions in Mt. Rainier National Park, and every region in Olympic National Park with the exception of the Upper Lena Lake region. Over the next several months, I will be exploring the effects of climate change on adult survival and body condition, using a long-term demographic dataset, for which I helped collect data for over the last 2 years. I will then feed these results into a population matrix model, and project this model forward through time, incorporating different climate scenarios. I project that these analyses will be completed by the end of April, 2015.

Deliverables/Research Products: (Please list.) This may include, but is not limited to presentations at the park(s), conferences/meetings attended, interpretive talks, published articles, electronic education products, etc.

1. Halabisky, M., Kissel, A.M., Ryan, M. Wetlands and climate change: bridging the gaps in science and on-the-ground adaptation. Pacific Northwest Climate Science Conference, Seattle, WA, September 10, 2014.

2. Project featured in the summer 2014 NPS Climate Change Response Newsletter

3. Presentation for NPS webinar "Climate change in America's National Parks". November 13, 2014.

4. Feature in Tacoma Tribune Climate Change in Mt. Rainier series (has not yet been published).

Include the links to any of your research products that are available electronically. If they are print products, please attach them at the end of this report as appendices.

- Link to youtube video of Pacific Northwest Climate Science Conference: https://www.youtube.com/watch?v=tHN3KfCDqEU&list=PLx3svrZZaMSVJ9sOICxABhPamnR6PXLPW

- Link to my blog about my research in the parks: https://wetcoastscience.wordpress.com/category/frogging-blogging/

- Link to NPS Climate Change Response Newsletter: http://www.nps.gov/subjects/climatechange/upload/Summer-2014.pdf

Additional Funding:
Were you able to use the Fellowship as leverage for securing other research funding? If so, please list the sponsor, program, and the amount of funding.

2014 National Park Service North Coast and Cascades Science Learning Network Award ($10,431)

Other:

- Please include information about additional products, presentations, or outcomes related to this research project that are not otherwise included in this report.

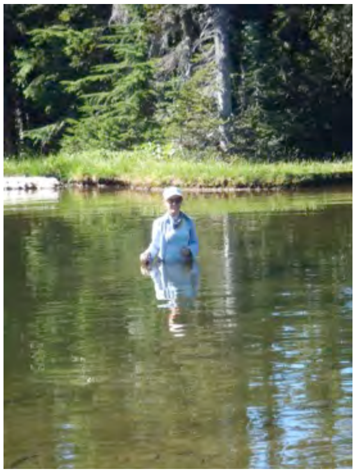
  - I am planning to attend both the GMW Society conference and Parks for Science conference in March of 2014.

  - With the additional funding from the Science Learning Network, I have proposed to create a website with outreach tools targeted for both school-aged children, and adults who are interested in the project. The website will feature stories about our work, information on the life-history of Cascades frogs and other montane amphibians, and video blogs from the field.

- Please share any anecdotes or stories from your project -- surprising discoveries, interesting happenings in the field, etc. -- that you think would be especially interesting for a general audience.

  One of my favorite parts from this past summer, was an impromptu outreach session with a group of girls (ages 12-14) from Wild Whatcom. They happened to be hiking around one of our research sites, and were interested in the amphibians they saw in the pond. My field crew and I took the opportunity to tell them about our research, including how we catch the frogs, measure, weigh, and tag them. The girls were very enthusiastic about our work and were very passionate about the amphibians in the pond that they would not have otherwise been exposed to.

Photographs:
Please include 3-5 photographs from your project. We are especially interested in any photos of you doing your research.
** In doing so, you are granting the University of Washington and the National Park Service permission to use your photos in publications (web, electronic, or print) related to the George M. Wright Climate Change Youth Initiative.*



A. Kissel measuring depth at a site in Spray Park, Mt. Rainier National Park, 2014.

Gavia Lertzman-Lepofsky, field assistant, collecting data at Spray Park, Mt. Rainier National Park, 2014.

Left. A. Kissel with the first Cascades frog of the season at Upper Lena, Olympic National Park, 2014.

Right: A. Kissel showing group of girls from Wild Whatcom how to insert a PIT tag into a Cascades frog in the 7 Lakes Basin of Olympic National Park, 2014.

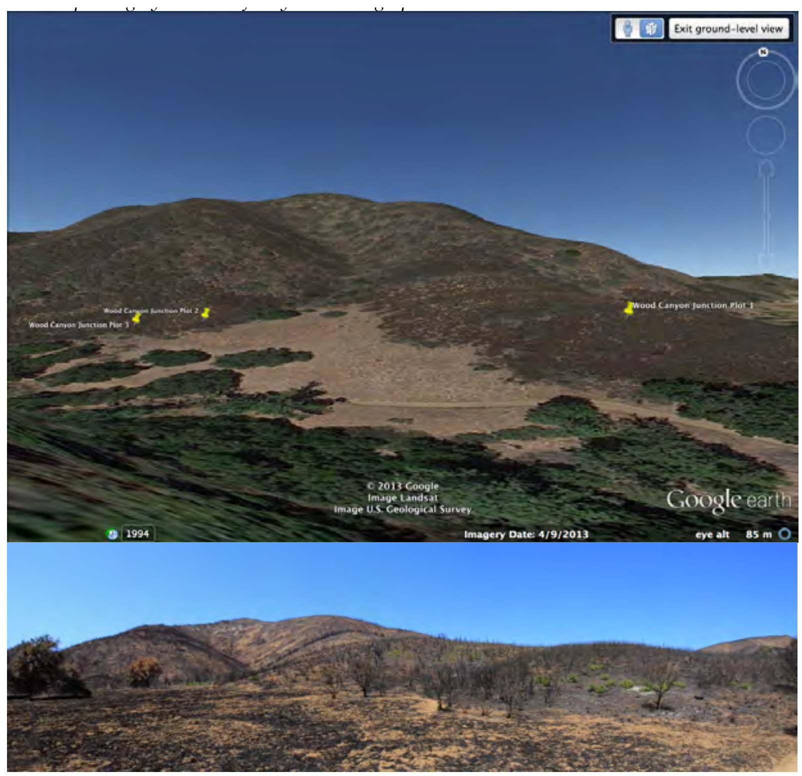
2013 NPS George M. Wright Climate Change Youth Initiative
Fellowship Research Final Report
December 31, 2014

Fellow Name: Aaron Ramirez
University: University of California, Berkeley
Start date: June 2013
End date: November 2014

Brief project summary:
Manipulative field experiment to study the interactions of drought and wildfire in the Santa Monica Mountains National Recreation Area, southern California.

Research Approach:
Please describe any significant changes to the original questions, hypotheses, or approach you used in your research.
The general approach of using a manipulative rainout experiment to study the interactions of drought and wildfire has remained unchanged. However, in response to a recent fire event that took place after the proposal was submitted, we have changed the focus of the study from unburned mature chaparral stands to recently burned stands. The out-of-season fire (expected to become a more frequent occurrence due to climate change) followed by one of the driest years on record (also expected to be more frequent in a climate change affected future), necessitated this adjustment to our research plan and makes the project even more in-line with the conservation goals of the Santa Monica Mountains National Recreation Area.

Location(s) of Research:
The field experiment took place within the Springs Fire burn area in the Santa Monica Mountains National Recreation Area (SMMNRA). The Springs Fire burned May 2, 2013 and burned >24,000 acres (NPS website). This was the 5th largest fire in recorded history for SMM and was also the earliest of the 5 largest fires. The specific site is located at the junction of Sycamore Canyon and Wood Canyon (34° 6'48.48"N, 119° 0'40.99"W; Figure 1). This area was selected for its easy access to dense post-fire chaparral and its easy sloping topography (to facilitate the construction of rainout shelters and watering treatments).



Key Findings:
Our results clearly demonstrate that availability of water is a primary driver of post-fire resprout success in A. fasciculatum. Furthermore, our findings suggest that southern California chaparral communities are experiencing high levels of mortality due to the extreme drought conditions in the region.

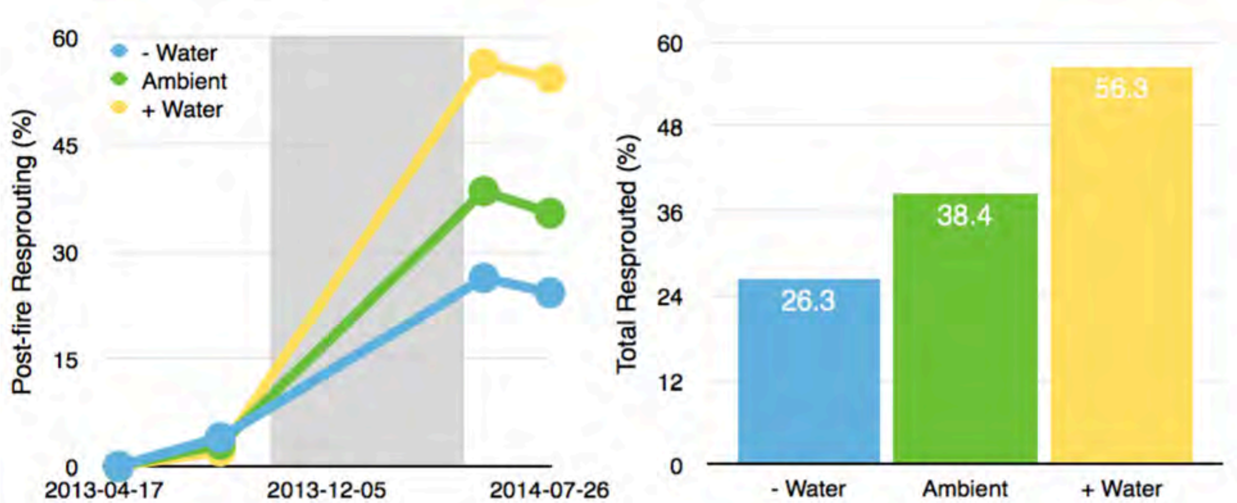


Figure 3. Post-fire resprouting as a percentage of the pre-fire population over time (left) and totaled for each treatment (right). Percentages are based on surveys of approximately 100 individuals per treatment. Grey box indicates time frame of water manipulations. These data suggest that water availability has a strong influence on initial resprouting ability.

Deliverables/Research Products: (Please list.) This may include, but is not limited to presentations at the park(s), conferences/meetings attended, interpretive talks, published articles, electronic education products, etc.

Include the links to any of your research products that are available electronically. If they are print products, please attach them at the end of this report as appendices.

- Interpretive signs near field site to inform public of on-going research on the interactions of drought and wildfire in Point Mugu State Park. See attached .pdf version of interpretive sign (Appendix A).

- Presentation to Santa Monica Mountains National Recreation Area (SMMNRA) stakeholders at SAMO Science Day, September 2014. See attached .pdf version of slides (Appendix B).

- Detailed Final Report prepared for NPS sponsors at SMMNRA. See attached copy of report (Appendix C).

Additional Funding:
Were you able to use the Fellowship as leverage for securing other research funding? If so, please list the sponsor, program, and the amount of funding.

Not Yet! Focus has shifted to securing additional funding for continued monitoring of established plots and for expansion of manipulated field experiments in the SMMNRA.

Other:

- Please share any anecdotes or stories from your project -- surprising discoveries, interesting happenings in the field, etc. -- that you think would be especially interesting for a general audience.

One of the key aspects of our project was adding water to plots for comparison with unwatered plots. Our original plan was to capture water from adjacent plots using rain gutters and storing the water in 55-gal. barrels to be distributed onto watered plots at our discretion. However, because the study took place during a record drought year in CA, there was not enough water captured to redistribute onto adjacent plots! In order to stick to the original experimental design we had to carry water using 2 x 5 gal. buckets and a yoke (see photo in Appendix B) up a large hill and fill the barrels manually! This was the equivalent of carrying 80+ lbs on your shoulders while you climb a large hill, tripping over burned stumps along the way! It took 6 trips to fill a single barrel and there were 3 barrels to fill, a total of ~18 trips! Needless to say, we slept very well at the end of these days. But the data look great and it was well worth the tired legs and bruised shoulders!

Photographs:
Please include 3-5 photographs from your project. We are especially interested in any photos of you doing your research.
* In doing so, you are granting the University of Washington and the National Park Service permission to use your photos in publications (web, electronic, or print) related to the George M. Wright Climate Change Youth Initiative.

See attached photographs in Appendix B. Original photographs available upon request.

NPS Post-Fire Drought Experiment

The structures on the hill are part of a scientific study investigating how drought affects the ability of native plants to regrow after fire. The structures manipulate the amount of rainfall that is able to get to the plants beneath, allowing us to observe how different levels of precipitation affect the regrowth of plants after fire.

Why do we care about drought?

California is currently experiencing one of the most extreme droughts in the past 150 years. In addition, predictions for the future are that climate change may further increase the frequency and intensity of droughts in southern California. Therefore, it is very important to develop a better understanding of how these droughts are likely to impact native plants here in Sycamore Canyon.

Fire + Drought: a dangerous synergy

Previous scientific studies have shown that when fire and drought strike simultaneously, native plant communities can fail to regenerate. Native CA plants are very good at recovering from the disturbance created by a wildfire. However, if that fire is followed by a drought, native plants may succumb to drought stress and die (see photo of dying resprout to the right). The current study aims to improve our understanding of these synergistic effects of fire and drought.

Who should I contact for more information?

The NPS Post-Fire Drought Experiment is funded by the George M. Wright Climate Change Youth Initiative Fellowship Program (ccyi.org), and is a collaborative project between the National Parks Service (nps.gov), California State Parks (parks.ca.gov), University of California, Berkeley (Ackerly Lab: ackerlylab.org, Dawson Lab: dawsonlab.synthasite.com), California State University, Bakersfield (Pratt Lab: csub.edu/~rpratt, Jacobsen Lab: csub.edu/~ajacobsen), and Pepperdine University (Davis Lab: faculty.pepperdine.edu/davis).

Primary Contact:
Aaron Ramirez
aramirez4916@berkeley.edu
George M. Wright Fellow
UC Berkeley - PhD Candidate

Fire and drought interactions affect outcomes in post-fire chaparral communities

Aaron Ramirez, George M. Wright Fellowship

Acknowledgements:

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- R. Brandon Pratt
- Anna L. Jacobsen
- Stephen D. Davis
- Todd Dawson
- David Ackerly

Collaborators

Marti Witter, PhD

Field Assistants

- R. Brandon Pratt
- Anna L. Jacobsen
- Stephen D. Davis
- Joseph Ramirez
- Manuel Ramirez
- Dave McGrath
- Max McGrath

Funding/Permits

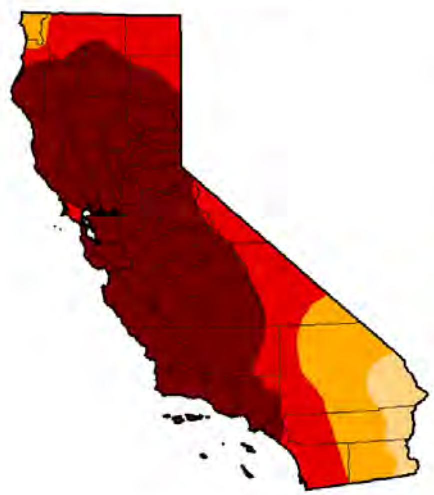
NPS GEORGE MELENDEZ WRIGHT CLIMATE CHANGE YOUTH INITIATIVE

Springs Fire 2013 - Santa Monica Mountains

www.earthobservatory.nasa.gov

U.S. Drought Monitor
California

September 2, 2014
(Released Thursday, Sep. 4, 2014)
Valid 8 a.m. EDT



Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	0.00	100.00	100.00	95.42	81.92	58.41
Last Week	0.00	100.00	100.00	95.42	81.92	58.41
3 Months Ago	0.00	100.00	100.00	100.00	76.68	24.77
Start of Calendar Year	2.61	97.39	94.25	87.53	27.59	0.00
Start of Water Year	2.63	97.37	95.95	84.12	11.36	0.00
One Year Ago	0.00	100.00	97.09	92.94	11.36	0.00

Intensity:
- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

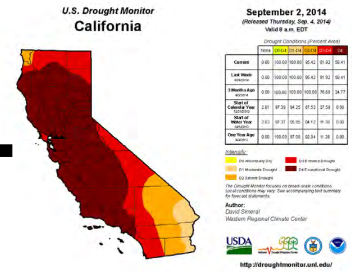
The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

Author:
David Simeral
Western Regional Climate Center

http://droughtmonitor.unl.edu/

Why Study Fire + Drought?

+

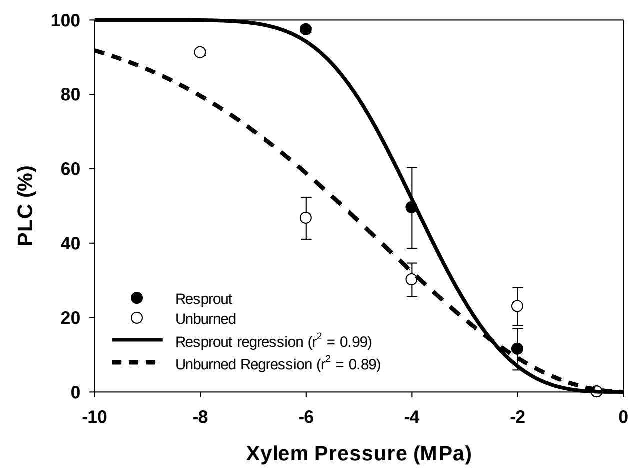


the “new normal”

Why Study Fire + Drought?

post-fire survival = life history bottleneck

Increased vulnerability to drought



Ramirez et al. 2012 - online resource 1

Why Study Fire + Drought?

post-fire survival = life history bottleneck

- increased vulnerability to drought stress
- altered community composition
- vegetation-type conversion

Global Change Biology

Global Change Biology (2014) **20**, 893–907, doi: 10.1111/gcb.12477

Mortality of resprouting chaparral shrubs after a fire and during a record drought: physiological mechanisms and demographic consequences

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Abstract

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Keywords: *Adenostoma*, carbohydrate starvation, cavitation, *Ceanothus*, chamise, wildfire, xylem

Received 11 July 2013 and accepted 24 October 2013

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Factors related to fire regime affect resprouting and have been well studied (Clarke *et al.*, 2013). For example, there is good evidence that resprout success is partially determined by the intensity of a fire (Rundel *et al.*, 1987; Moreno & Oechel, 1993; Borchert & Odion, 1995; Odion & Davis, 2000; Keeley, 2006b; Wright & Clarke, 2007). Moreover, fire frequency and seasonal timing of fire are important factors affecting resprouting for some species (Zedler *et al.*, 1983; Rundel *et al.*, 1987; Haidinger & Keeley, 1993; Franklin *et al.*, 2001; Lloret *et al.*, 2003; Wright & Clarke, 2007; Enright *et al.*, 2011). Beyond fire regime, there are plant life history and functional traits that influence the success of resprouts (Moreira *et al.*, 2012).

Successful resprouting after crown fire requires that a plant survive and compete to reclaim the space lost in the fire. This requires buds that can rapidly form new

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Global Change Biology

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Mortality of resprouting chaparral shrubs after a fire and during a record drought: physiological mechanisms and demographic consequences

R. BRANDON PRATT[1], ANNA L. JACOBSEN[1], AARON R. RAMIREZ[2], ANJEL M. HELMS[3], COURTNEY A. TRAUGH[1], MICHAEL F. TOBIN[4], MARCUS S. HEFFNER[3] and STEPHEN D. DAVIS[3]

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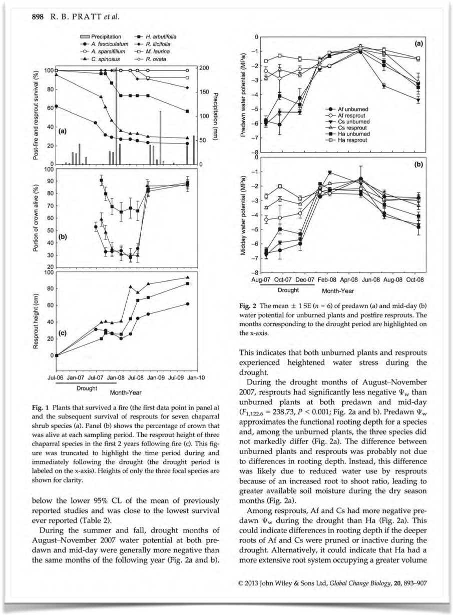


Fig. 1 Plants that survived a fire (the first data point in panel a) and the subsequent survival of resprouts for seven chaparral shrub species (a). Panel (b) shows the percentage of crown that was alive at each sampling period. The resprout height of three chaparral species in the first 2 years following fire (c). This figure was truncated to highlight the time period during and immediately following the drought (the drought period is labeled on the x-axis). Heights of only the three focal species are shown for clarity.

below the lower 95% CL of the mean of previously reported studies and was close to the lowest survival ever reported (Table 2).

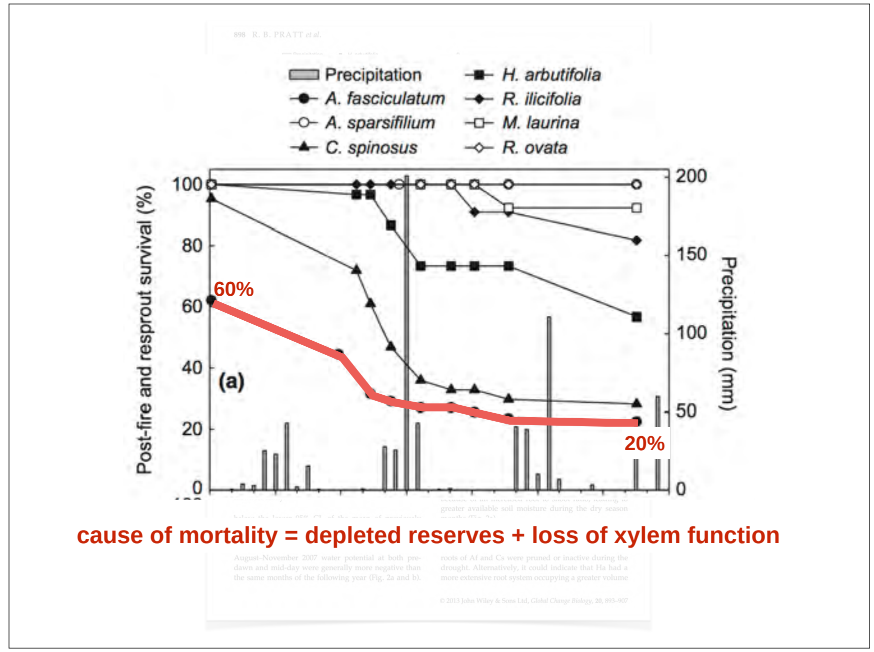
During the summer and fall, drought months of August–November 2007 water potential at both predawn and mid-day were generally more negative than the same months of the following year (Fig. 2a and b).

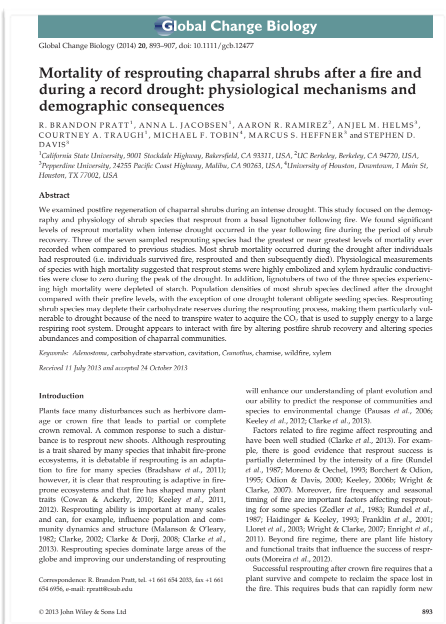
Fig. 2 The mean ± 1 SE (n = 6) of predawn (a) and mid-day (b) water potential for unburned plants and postfire resprouts. The months corresponding to the drought period are highlighted on the x-axis.

This indicates that both unburned plants and resprouts experienced heightened water stress during the drought.

During the drought months of August–November 2007, resprouts had significantly less negative Ψ_w than unburned plants at both predawn and mid-day ($F_{1,122.6}$ = 238.73, P < 0.001; Fig. 2a and b). Predawn Ψ_w approximates the functional rooting depth for a species and, among the unburned plants, the three species did not markedly differ (Fig. 2a). The difference between unburned plants and resprouts was probably not due to differences in rooting depth. Instead, this difference was likely due to reduced water use by resprouts because of an increased root to shoot ratio, leading to greater available soil moisture during the dry season months (Fig. 2a).

Among resprouts, Af and Cs had more negative predawn Ψ_w during the drought than Ha (Fig. 2a). This could indicate differences in rooting depth if the deeper roots of Af and Cs were pruned or inactive during the drought. Alternatively, it could indicate that Ha had a more extensive root system occupying a greater volume

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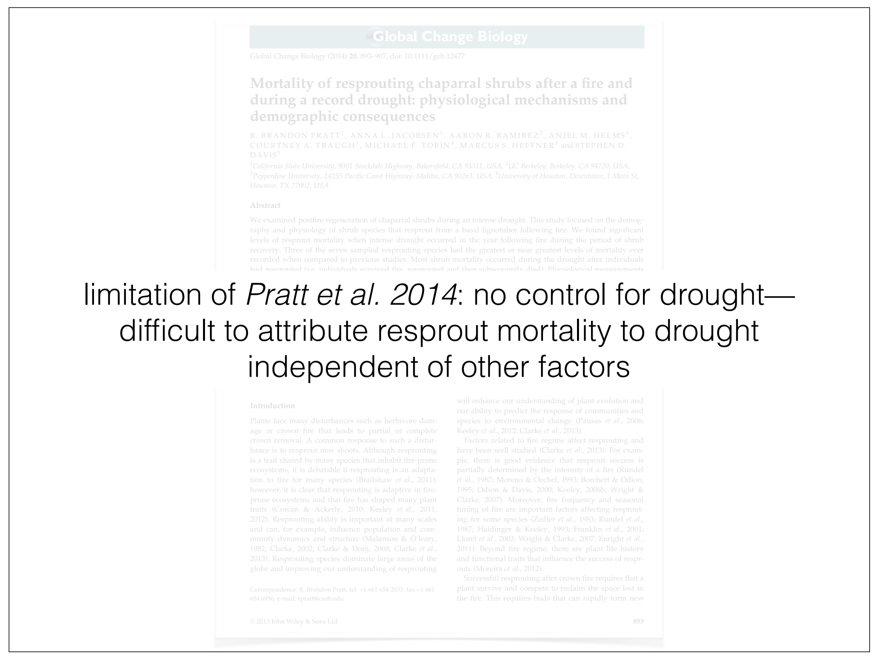


NPS GEORGE MELENDEZ WRIGHT
CLIMATE CHANGE
YOUTH INITIATIVE

Goals:

1. Improve understanding of drought + wildfire:
How does drought affect resprout success?

2. Proof of concept:
Can rainout shelters be used to study drought effects in post-fire chaparral?

Methods:

Springs Fire 2013, Sycamore Canyon near Wood Canyon

Methods:

9 (5 x 5 m) plots near sycamore canyon & wood canyon

Methods:

tagged ~33 chamise stumps in each plot

Methods:

-water	ambient	+water

33 individuals x 3 watering treatments x 3 sites = 299 plants

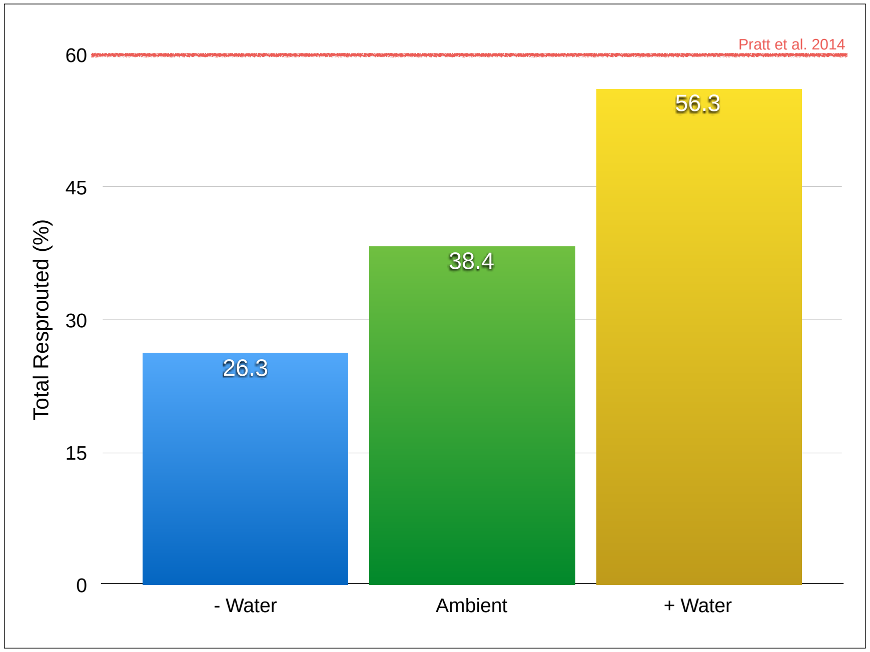
What We Measured:

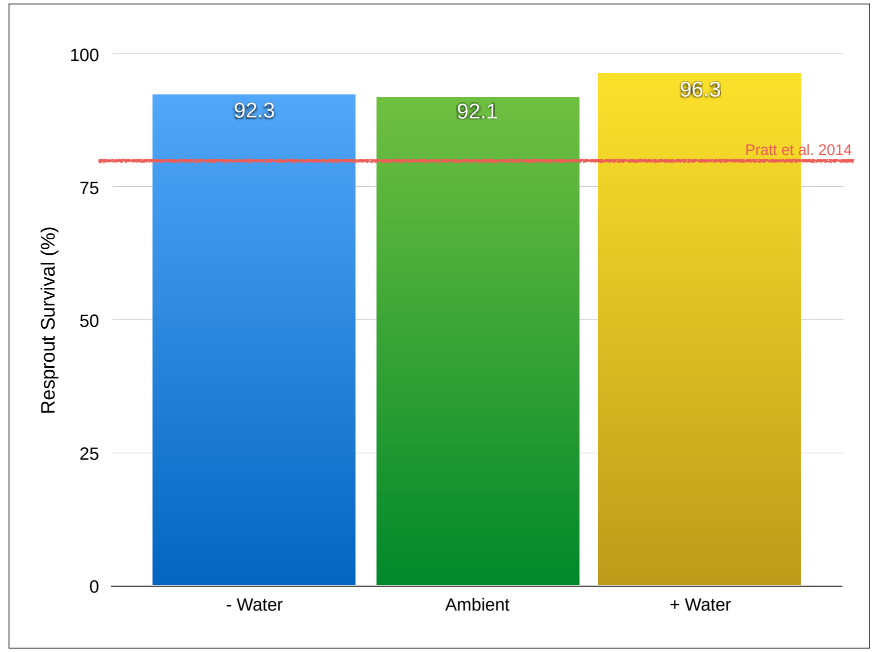
1. post-fire survival = total resprouted
2. resprout vigour = plant height
3. post-resprout survival = resprout mortality

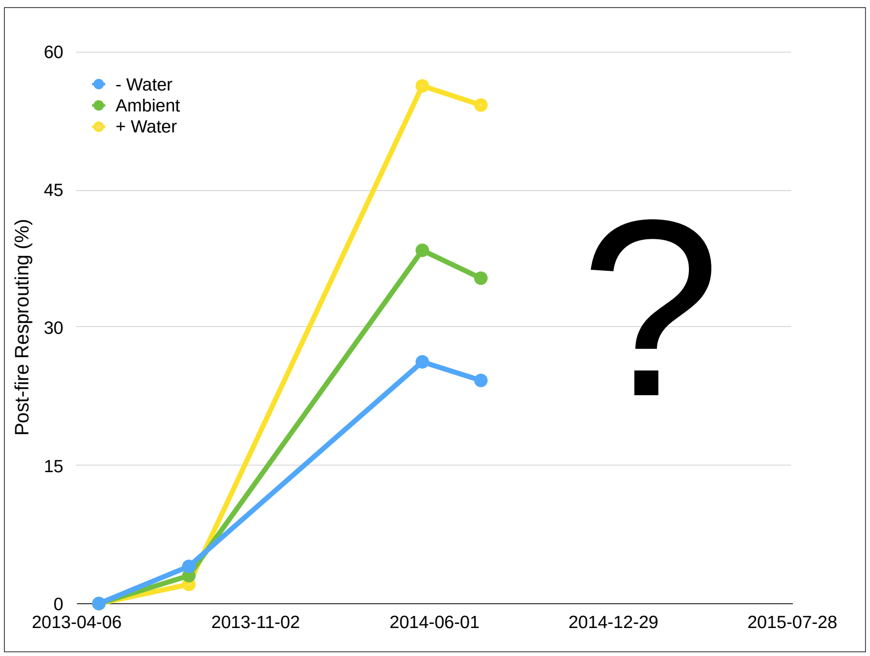
What did we find?

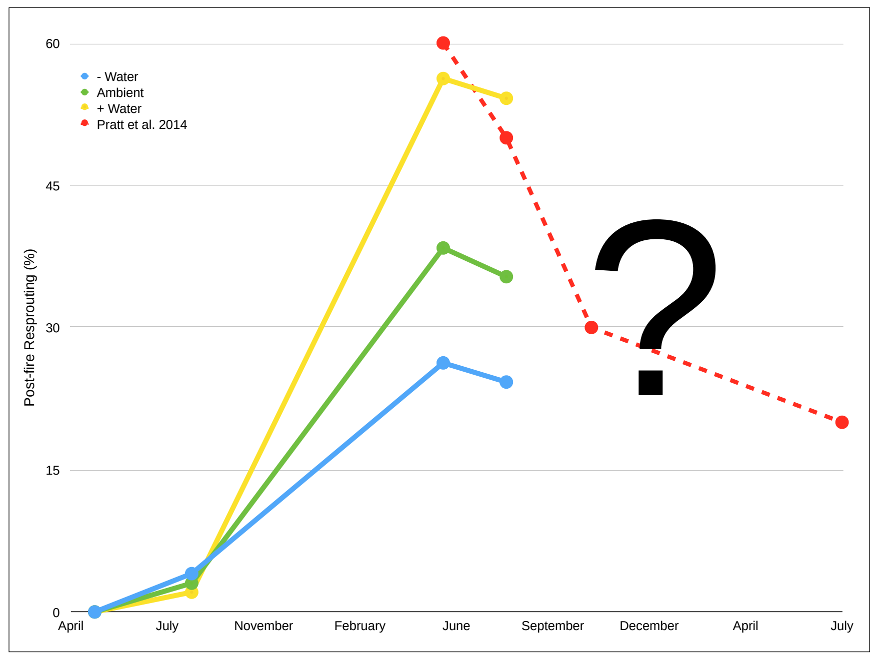
-water

+water


Pratt et al. 2014
60
45
30
15
0
Total Resprouted (%)
26.3
38.4
56.3
- Water
Ambient
+ Water


100
75
50
25
0
Resprout Survival (%)
92.3
92.1
96.3
Pratt et al. 2014
- Water
Ambient
+ Water

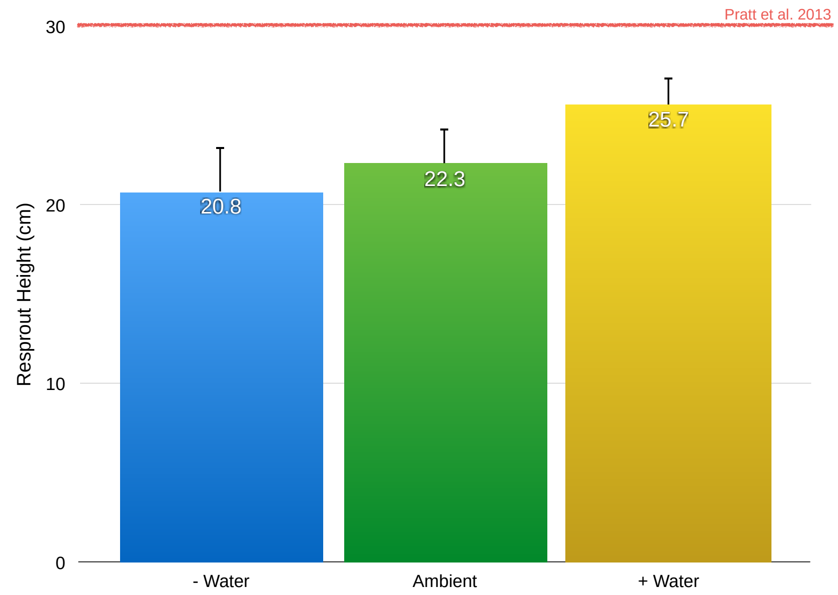

60
45
30
15
0
- Water
Ambient
+ Water
Post-fire Resprouting (%)
?
2013-04-06
2013-11-02
2014-06-01
2014-12-29
2015-07-28


60
45
30
15
0
- Water
Ambient
+ Water
Pratt et al. 2014
Post-fire Resprouting (%)
?
April
July
November
February
June
September
December
April
July

Conclusion:

1. **Water is important!**
- post-fire survivorship depends on amount of wet-season precipitation.
- even *small* amounts of water make a *big* difference.

2. **Rainout shelters work!**
- manipulating surface water works despite deep roots.
- future studies on post-fire drought should consider using rainouts to manipulate water.



Why Study Fire + Drought?

A. fasciculatum, C. megacarpus, M. laurina

→ *A. fasciculatum, C. megacarpus, M. laurina*

→ *A. fasciculatum, C. megacarpus, M. laurina*

Why Study Fire + Drought?

chaparral auto-succession

vegetation-type conversion

Effects of experimental drought on post-fire chamise recovery in the Santa Monica Mountains National Recreation Area

Aaron Ramirez[1], David Ackerly[1], Todd Dawson[1], Brandon Pratt[2], Anna Jacobsen[2], and Stephen Davis[3]

[1]University of California, Berkeley; [2]California State University, Bakersfield; [3]Pepperdine University

Abstract

Future climate change predictions for southern California suggest warmer temperatures and more variable rainfall, both are expected to contribute to an increase in *global-change-type drought* in the region. In southern California shrublands (i.e. chaparral), drought may interact with fire in ways that limit the resilience of these diverse and important plant communities. We used a controlled field experiment to study the impacts of drought on the recovery of *Adenostoma fasciculatum*—a dominant chaparral shrub—after a recent wildfire. The goal of this research was to document the responses of *A. fasciculatum* to experimental drought and evaluate drought as a potential driver of post-fire mortality. Our results clearly demonstrate that availability of water is a primary driver of post-fire resprout success in *A. fasciculatum*. Furthermore, our findings suggest that southern California chaparral communities are experiencing high levels of mortality due to the extreme drought conditions in the region.

Introduction

Future climate change predictions highlight the need for a more comprehensive, mechanistic understanding of the impacts of future drought on native California plant communities. Current models predict California will experience warmer average temperatures, longer seasonal droughts, and more frequent heat waves (IPCC 2007, 2013). In addition, there is evidence that generally warmer temperatures will increase future evapotranspiration and hydrologic variability to such a degree that plants will experience drier conditions even in areas predicted to experience increased wet-season precipitation (Micheli et al. 2012, Flint et al. 2012, Knowles and Cayan 2002, Cayan et al. 2007, 2009). Ergo, the future for California plants is a drier one.

Drought impacts may be greatest for the evergreen shrub communities (i.e. chaparral) that inhabit the semi-arid winter rainfall region of southern California. Southern California chaparral communities experience an annual 6-8 month dry period that is characterized by a co-occurrence of high temperatures, high evaporative demand, and low soil moisture (Bhaskar et al. 2007, Cowling et al. 2005). During extreme episodes of these seasonal droughts, chaparral shrubs can experience significant dieback and shrub mortality (Davis et al. 2002, Schlesinger et al. 1982, Schlesinger and Gill 1978, Horton and Kraebel 1955). Furthermore, recent work in this system, suggests that drought can interact with fire by driving post-fire mortality of delicate seedlings and resprouts and altering the composition of chaparral communities (Pratt et al. 2014, Frazer and Davis 1988).

We can further our understanding of drought responses in the California chaparral by employing manipulative field studies. Chaparral drought responses have been studied via un-manipulated field experiments (e.g., Pratt et al. 2007, Paddock 2006, Davis et al. 2002) and one controlled common garden study using seedlings (Pratt et al. 2008). While these previous studies provide a useful foundation and set of testable hypotheses, many important questions remain about the sensitivities of particular shrub species and functional types that can best be addressed with manipulated field experiments similar to those recently conducted in other semi-arid systems (e.g.,West et al., 2012). Such an approach to studying the drought responses in chaparral communities in CA would be incredibly useful for trying to predict the outcomes of future drought scenarios.

Here we present findings from a manipulative field experiment using rainout shelters to study the impacts of intensified drought conditions on post-fire chaparral shrubs in the Santa Monica Mountains National Recreation Area, southern California. By selectively removing water inputs from controlled areas we effectively created a "water stress" treatment that was compared to co-occurring "control" plants. We used this system to explore the responses of *A. fasciculatum*—a dominant resprouting shrub species—to this experimentally induced drought.

Methods

Study Site and Study Species

The field experiment took place within the Springs Fire burn area in the Santa Monica Mountains National Recreation Area (SMMNRA). The Springs Fire burned May 2, 2013 and burned >24,000 acres (NPS website). This was the 5th largest fire in recorded history for SMM and was also the earliest of the 5 largest fires. The specific site is located at the junction of Sycamore Canyon and Wood Canyon (34° 6'48.48"N, 119° 0'40.99"W; Figure 1). This area was selected for its easy access to dense post-fire chaparral and its easy sloping topography (to facilitate the construction of rainout shelters and watering treatments; see below). The study focuses on resprouting individuals of *Adenostema fasciculatum*—the dominant species at this site and over much of the region.

Figure 1. Image of field site vicinity at the junction of Sycamore Canyon and Wood Canyon. Yellow pins indicate plot locations at the site.

Water manipulations and Experimental Design

We established three sets of three plots (3 x 3 = 9 plots in total). Each plot was 5 x 5 meters and had similar characteristics and numbers of burned stumps (i.e. similar pre-fire density). In each group of 3 plots, there was one plot with 100% rain exclusion (- *Water* treatment), one plot with 0% rain exclusion (*Ambient* control), and one plot with 0% rain exclusion + additional watering (+ *Water* treatment). The difference in rain exclusion between plots was achieved by varying the angle of transparent polycarbonate roof tiles on steel-framed rainout shelters (Figure 2). - *Water* plots had flat roof tiles so that 100% of precipitation was excluded from the plot. Excluded water was collected using rain gutters, stored in 55-gal barrels, and piped onto the + *Water* plots during simulated rain events. *Ambient* and + *Water* plots had the same steel-framed rainout shelters but with roof tiles tilted at 30° in order to create the same shading effect of treatment plots but allowing rain to run onto the plot. The + *Water* treatment consisted of monthly episodes of simulated rain events during the late winter-early summer (February - June 2014). Each simulated rain event involved applying 55-gal. of water via drip irrigation evenly throughout the 5 x 5 meter plot. This approach simulated an extension of the rainy season and increased the annual precipitation totals for the + *Water* treatment. Approximately 33 *A. fasciculatum* plants were tagged and followed in each plot, for a total of 99 plants per treatment, and just under 300 plants included in the study. This sample size was chosen to maximize the number of plants sampled in each plot while excluding plants near the edge of each plot to prevent edge effects.

Figure 2. Image of rainout shelters. Flat roofed shelter (far left) excluded 100% of wet season precipitation. Shelters with angled roof panels (center & far right) allowed ambient rainfall to fall on the plots.

Measurements of resprouting, growth, and mortality

The initial survey in August 2013 involved tagging burned *A. fasciculatum* stumps in each plot and recording which plants were resprouting, the height of resprouting shoots, and presence of any resprout dieback (estimated as a % of the resprouting plant). Measurements of height, canopy dieback, and plant mortality were updated several times during the following dry season. These repeated surveys allowed us to monitor the post-fire resprouting dynamics and draw conclusions about the effects of drought on resprout growth and mortality.

Results

Post-fire Resprouting

The initial survey in August 2013 revealed that less than 5% of the pre-fire populations for all three treatments were resprouting (Figure 3). Following the rainy season and deployment of rainout shelters, resprouting had increased in all treatments by the May 2014 survey (Figure 3). +*Water* treatments had the highest proportion of resprouting plants with ~56% of the pre-fire population resprouting (Figures 3). Both the *Ambient* and -*Water* treatments had considerably fewer individuals survive the first rainy season, with only 38% and 26% of their pre-fire populations resprouting by May 2014, respectively.

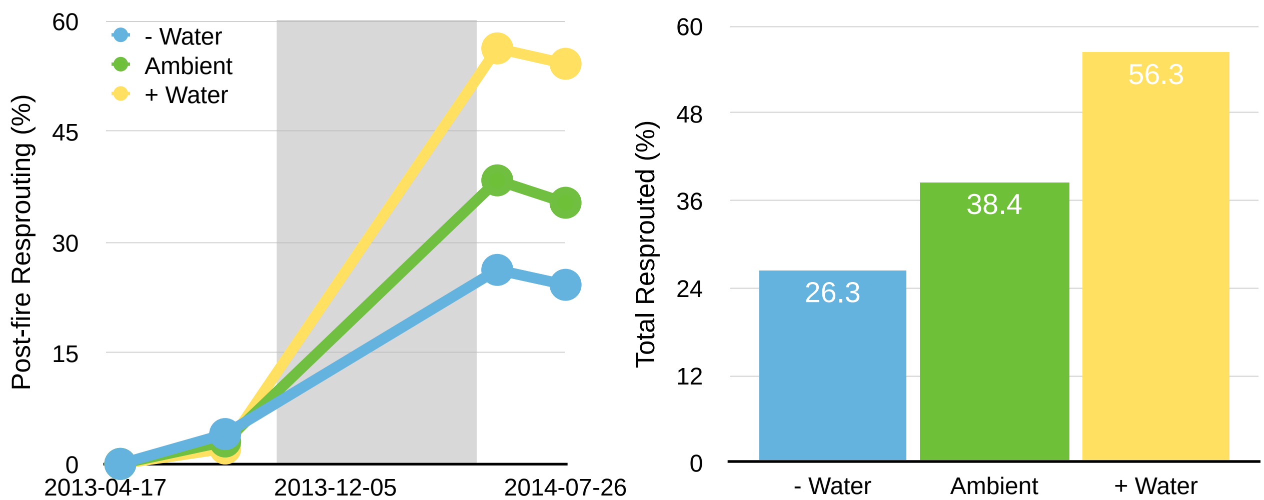


Figure 3. Post-fire resprouting as a percentage of the pre-fire population over time (left) and totaled for each treatment (right). Percentages are based on surveys of approximately 100 individuals per treatment. Grey box indicates time frame of water manipulations. These data suggest that water availability has a strong influence on initial resprouting ability.

Resprout Survival

As of September 2014, there was very little resprout mortality in any treatment (Figure 4). No treatment had less than 92% survival by the end of the 2014 summer.

Discussion

Evidence of drought-driven effects on initial resprouting ability

This study provides evidence that different levels of post-fire precipitation result in different levels of initial post-fire resprouting ability. The fact that our plots which received the most water (i.e. + *Water* plots) had the most plants resprouting and those with the least amount of water (- *Water* plots) had the fewest resprouting, argues compellingly that water is a chief determinant of how many plants resprout after fire, independent of other factors. Recent work on the ecology of resprouting has argued that the initial ability to resprout is determined more by factors like the destruction of buds and depletion of stored reserves than drought (Moriera et al., 2012). Previous work in the Santa Monica Mountains has also assumed that initial resprouting percentages are driven by factors other than drought (e.g., Pratt et al. 2014). However, the results of our manipulated field study suggest that post-fire water availability is another factor that is capable of affecting initial resprouting ability, possibly by limiting the turgor pressure required for initiation of resprout growth.

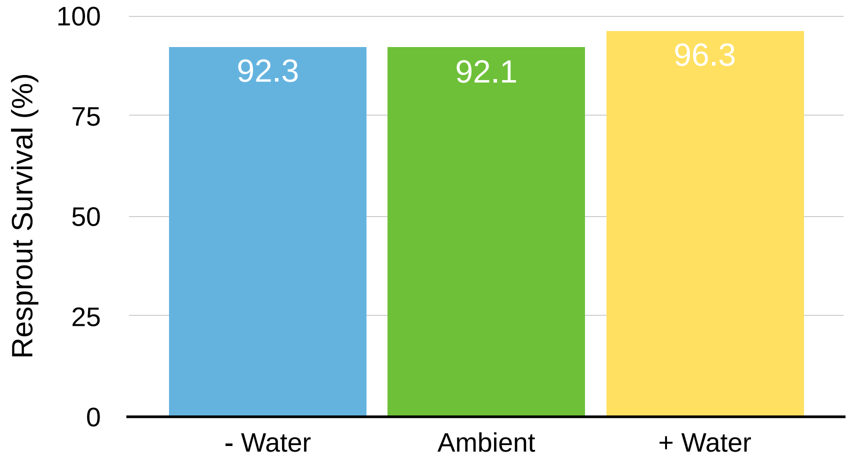


Figure 4. Resprout survival as a percentage of the total resprouted. These data suggest that plants that were able to resprout have so far survived the drought.

Causes and Implications of low resprout success

Despite the high resprout survival to date, the total resprouting percentages in the present study—driven by low initial resprouting—are already some of the lowest ever recorded (see Pratt et al. 2014 for summary of other published studies). Even plants in the + *Water* treatments—where we increased precipitation above ambient levels—have resprouting percentages lower than the mean resprout survival (64%) reported in 47 previous studies. The severe limitations in resprouting ability we observed across all treatments are likely due to two factors: a record-breaking regional drought and season of the fire. Most of southern California is currently experiencing record drought conditions. This means that our experimental drought conditions were overlapping with natural drought conditions. Therefore, all of our treatments, even the + *Water*, were affected by drought. Second, the Springs Fire started in May 2013 which was very early compared to the normal fall fire regime that characterizes the area. Fires during the late spring/early summer occur at a time when plants are metabolizing stored reserves to support new growth (Rundel 1981). This means that fewer stored reserves are available after the fire to support root crown metabolism and resprout growth. The combination of record drought and reduced starch reserves are likely responsible for the low resprouting ability we observed across our plots.

The lack of successful resprouting has ominous implications for the recovery of the pre-fire community. *A. fasciculatum* survives fire by resprouting and recruiting from a soil-stored seed bank. In a recent study of post-fire recovery in a Santa Monica Mountains —also during record drought conditions—*A. fasciculatum* experienced high mortality of pre-fire individuals due to low initial resprouting and subsequent resprout mortality (Pratt et al. 2014). However, the loss of resprouting individuals in that study was offset by seedling recruitment. In the present study, the low resprout success of *A. fasciculatum* is likely to have a larger impact on the post-fire community due to low seedling recruitment (personal observation). Future monitoring is necessary to fully understand the implications of the observed low resprout survival.

Future project plans

Future plans are focused on continued monitoring of post-fire resprouting in treatment and control plots. To date, watering treatments have had a large effect on post-fire resprouting but significant mortality of resprouts has yet to be observed. The results of Pratt et al. (2014) suggest that late fall/early winter (i.e. end of the drought) may be crucial sampling periods for capturing patterns of resprout mortality. Therefore, we plan to seek funding to continue monitoring these plots for an additional year.

Completed and Anticipated Research Products

Completed research products include: (1) interpretive signs designed to educate visitors of the Big Sycamore Canyon recreational area about the ongoing drought experiment, (2) a presentation to NPS employees and volunteers at the SMMNRA Science Day 2014, and (3) this report. Anticipated research products include (1) a peer-reviewed publication following completion of additional sampling and (2) use of the data to seek funding for a larger scale project in the SMM employing rainout shelters to study the affects of drought in southern California chaparral communities.

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2013 NPS George M. Wright Climate Change Youth Initiative
Fellowship Research Final Report
December 31, 2014

Fellow Name: Derek Young
University: University of California, Davis
Start date: June 2013
End date: May 2015

Brief project summary:

This project is designed to evaluate the climatic tolerance of conifer populations throughout the Sierra Nevada, particularly at the southern range limit of coast Douglas-fir (*Pseudotsuga menziesii* var. *menziesii*) near Yosemite National Park, and to evaluate the potential for evolutionary adaptation to the hotter, drier climates anticipated throughout this region in the future. I will particularly look for evidence of local adaptation (i.e., that populations occupying drier environments are more tolerant of drought stress), as this may indicate the potential for natural and/or managed gene flow to facilitate adaptation of populations to changing climates.

Research Approach:
Please describe any significant changes to the original questions, hypotheses, or approach you used in your research.

The project centers around an analysis of annual radial tree growth data obtained from tree cores (from adult trees) and stem cross-sections (from saplings) from 5 to 15 individuals of each of the dominant conifer species in each site. I have sampled trees from more than 50 populations distributed along climatic gradients (latitude, elevation, and aspect) throughout the central and northern Sierra Nevada, with particular emphasis around the Yosemite National Park area. I will relate annual growth increments to annual climate variables to understand which climate variables are most limiting to tree growth and to estimate the extent of each population's tolerance of fluctuations in these variables. I will examine how apparent limits in climatic tolerance differ by species, by mean population climate, and by proximity to the species' geographical and climatic range limits. I will interpret correlations between these variables and climatic tolerance limits as evidence of potential local adaptation that can provide a window into performance of populations throughout the study area under a changing climate.

With approval of the GMW Fellowship administrators and my Yosemite National Park contacts, I modified the approach that I originally proposed to the GMW committee. Originally, in addition to using phenotypic data (i.e., radial growth measurements) to search for local adaptation and infer adaptive capacity, I had proposed to include a molecular genetic (genomics) component. After receipt of the award, I consulted with numerous genomics experts and arrived at the conclusion that including a genomic component would be very expensive, would require a very complex and specialized analysis, and would yield little information beyond that obtainable through phenotypic data. I therefore decided to drop the genomic component and direct more attention to the phenotypic analysis

Location(s) of Research:

The project is located in mixed-conifer forest throughout the central and northern zones of the west slope of the Sierra Nevada, with particular emphasis in the greater Yosemite National Park area.

Key Findings:

The analysis is currently in its early stages; I expect to have results in 2015.

Deliverables/Research Products: (Please list.) *This may include, but is not limited to presentations at the park(s), conferences/meetings attended, interpretive talks, published articles, electronic education products, etc.*

Include the links to any of your research products that are available electronically. If they are print products, please attach them at the end of this report as appendices.

Anticipated products:

- Presentation to park managers and the public at the Yosemite Forum in 2015
- Presentation to scientists at the Yosemite Fire and Hydroclimate Symposium in 2015
- Presentation to scientists at the Ecological Society of America meeting in 2015 or 2016
- Presentation to Federal land managers at the U.S. Forest Service Pacific Southwest Region Ecology meeting in 2015 or 2016
- Publication of a research brief through the U.S. Forest Service Pacific Southwest Region
- Publication of a scientific journal article (target journal: Global Change Biology)
- Publication of one or more popular press articles (target media outlets: San Francisco Chronicle environment blog, UC Davis Ecology Graduate Student Association blog, others)
- Publication of radial growth images and data in one or more publicly-available ecological data clearinghouses

Additional Funding:

Were you able to use the Fellowship as leverage for securing other research funding? If so, please list the sponsor, program, and the amount of funding.

- U.S. Forest Service; Pacific Southwest Ecology Program; In-kind support: three-member field crew for five weeks (approximate value: $15,000)

Other:

- *Please include information about additional products, presentations, or outcomes related to this research project that are not otherwise included in this report.*

- *Please share any anecdotes or stories from your project -- surprising discoveries, interesting happenings in the field, etc. -- that you think would be especially interesting for a general audience.*

Our work involved collection of tree cores near some iconic locations within Yosemite Valley. One site is at the base of the El Capitan cliff, which draws rock climbers from around the world. Another site is near the base of Bridalveil Fall. Although these sites are within ½ mile of each other, the El Capitan site receives much greater sun exposure and therefore experiences much greater drought stress. Thus, the Bridalveil site and similar areas may serve as "refuges" or "stepping stones" for Yosemite Valley tree populations as conditions continue to dry throughout the park. The tree ring analysis will reveal whether tree populations are uniquely adapted to the highly contrasting conditions at these very closely-spaced sites.

Additionally, some of our research during this field season was conducted within the perimeter of the 2013 Rim Fire, which created unique working conditions (e.g., extreme safety precautions due to the potential for falling trees and branches, and unavoidably becoming covered in black soot each day from constant contact with charred trunks).

Photographs:

Please include 3-5 photographs from your project. We are especially interested in any photos of you doing your research.

** In doing so, you are granting the University of Washington and the National Park Service permission to use your photos in publications (web, electronic, or print) related to the George M. Wright Climate Change Youth Initiative.*

Note: I have several other photos (particularly of me) to include once I receive them from my research assistants.

Michelle working within the perimeter of the 2013 Rim Fire near Hodgdon Meadow in Yosemite National Park.


Michelle measuring a ponderosa pine tree at the base of El Capitan in Yosemite Valley.

An early-morning view of Yosemite Valley on the way to our first field site of the day.

Derek collecting an increment core from a Douglas-fir tree near Wawona in Yosemite National Park.

Increment cores collected from conifers in Yosemite National Park. The cores are mounted, sanded, and ready for measuring.