



GEORGE MELENDEZ WRIGHT
YOUNG LEADERS
IN CLIMATE CHANGE

Fiscal Year 2017
Accomplishment Report

Introduction

The Climate Change Response Program (CCRP) successfully conducted the third year of the George Melendez Wright Initiative for Young Leaders in Climate Change (YLCC). The YLCC is a competitive internship program in which high-achieving undergraduate and graduate students conduct rigorous and innovative projects to address high priority climate change management challenges in National Park Service (NPS) park and program offices. The YLCC is an approved Direct Hire Authority for Resource Assistant Internship Program; interns who successfully complete the YLCC and the requirements of their academic degree program are eligible for noncompetitive hiring. The CCRP administers this initiative in partnership with the University of Washington (UW).

Accomplishments

The CCRP received and paneled 28 project proposals between September and October 2016 from NPS park and program offices. An interdisciplinary panel awarded eleven projects spanning a range of disciplines and resource foci across multiple regions and biomes in the U.S.

The UW launched a call for student applications on the website www.parksclimateinterns.org. We received 312 applications from graduate students, upper-level undergraduate students (juniors and seniors), and recent graduates. The CCRP convened eleven separate panels consisting of (at minimum) the park/program supervisor and a representative from the CCRP to review 20-50 student applications, interview 2-4 top candidates, and award the projects to successful interns. The interns were selected from universities across the United States, and represented a diversity of age (22-29 years), gender (62% female) and ethnic backgrounds (55% minority or multi-racial). See Attachments A and B for intern and project information.

The CCRP and UW collaborated to provide project supervisors and interns with an orientation to the YLCC Initiative and UW employment requirements and provide ongoing support throughout the summer. Interns completed their projects between May and September 2017. A final report, related deliverables, and evaluation are available from each park or program. Both interns and their NPS supervisors provided extremely positive feedback regarding all aspects of the initiative.

Career mentorship and professional development are core elements of the YLCC experience. Each intern and supervisor completed a Leadership Development and Mentorship Plan that establishes the intern's project and professional goals at the beginning of the summer. The CCRP then organized a Professional Development Symposium on August 8-9 in Fort Collins, CO to expose interns to leaders in their chosen fields and provide them with useful tools and knowledge to launch federal careers. There are now 35 alumni who possess, or will possess following completion of their degree program, direct hire eligibility.

The National Park Service provided a total of \$145,668 to administer the 2017 YLCC season.

Please review the following attachments for more detailed information regarding the outcomes of this initiative. Items available upon request include: (1) the YLCC Handbook; (2) an agenda for the Professional Development Symposium, (3) video recordings of student presentations, (4) supervisor and intern orientation slide decks and recordings, (5) Leadership Development and Mentorship Plans, (6) evaluations, and (7) additional project deliverables.

FY 2017 Young Leaders in Climate Change Positions

Region	Park/Program	Project Title
PWR	Devils Postpile NM	What's Blooming in the Cold Air Pool?
SER	Everglades NP	Changes in Roseate Spoonbill Colony Distribution
NER	Fire Island NS	Climate Change Science Communication in the Northeast
MWR	Great Lakes REC / Indiana Dunes NL	Identification, Inventory, and Characterization of Vernal Pools to Assess Vulnerability to Climate Change
IMR	Navajo NM	Preserving Site Access and Cliff Dwellings in the Face of Arroyo Incising and Expansion
PWR	Olympic NP	Vanishing Ice. Understanding the Rate and Extent of Glacier Loss in the Olympic Mountains
WASO	Rocky Mountain NP	Establishing Long Term Monitoring Project for Pikas in Rocky Mountain National Park
NER	Salem Maritime / Saugus Iron Works NHS	Establish Climate Change Monitoring on Cultural Landscapes and Historic Structures
PWR	Santa Monica Mountains NRA	Develop Models for Community-Based Dialogues about Climate Change in Los Angeles
NER	Shenandoah NP	Shenandoah Salamander: Climate Change Casualty or Survivor? Teacher Workshop
SER	South Florida Caribbean Network	Reef Temperature Wrangler for South Florida National Parks

List of Attachments

Attachment A Project Map

Attachment B Project and Intern Information

Attachment C Financial Information

Attachment D Project Reports 1-11

1. Sophia Chau, DEPO	5. Olivia Beaulieu, NAVA	9. Ivan Bermejo, SAMO
2. Elizabeth Lago, EVER	6. Justin Pflug, OLYM	10. Katie Halpin, SHEN
3. Minh Phan, FIIS	7. Laura Getts, ROMO	11. Brandon Araujo, SFCN
4. Nemesis Ortiz-Declet, INDU	8. Shanasia Sylman, SAMA/SAIR	

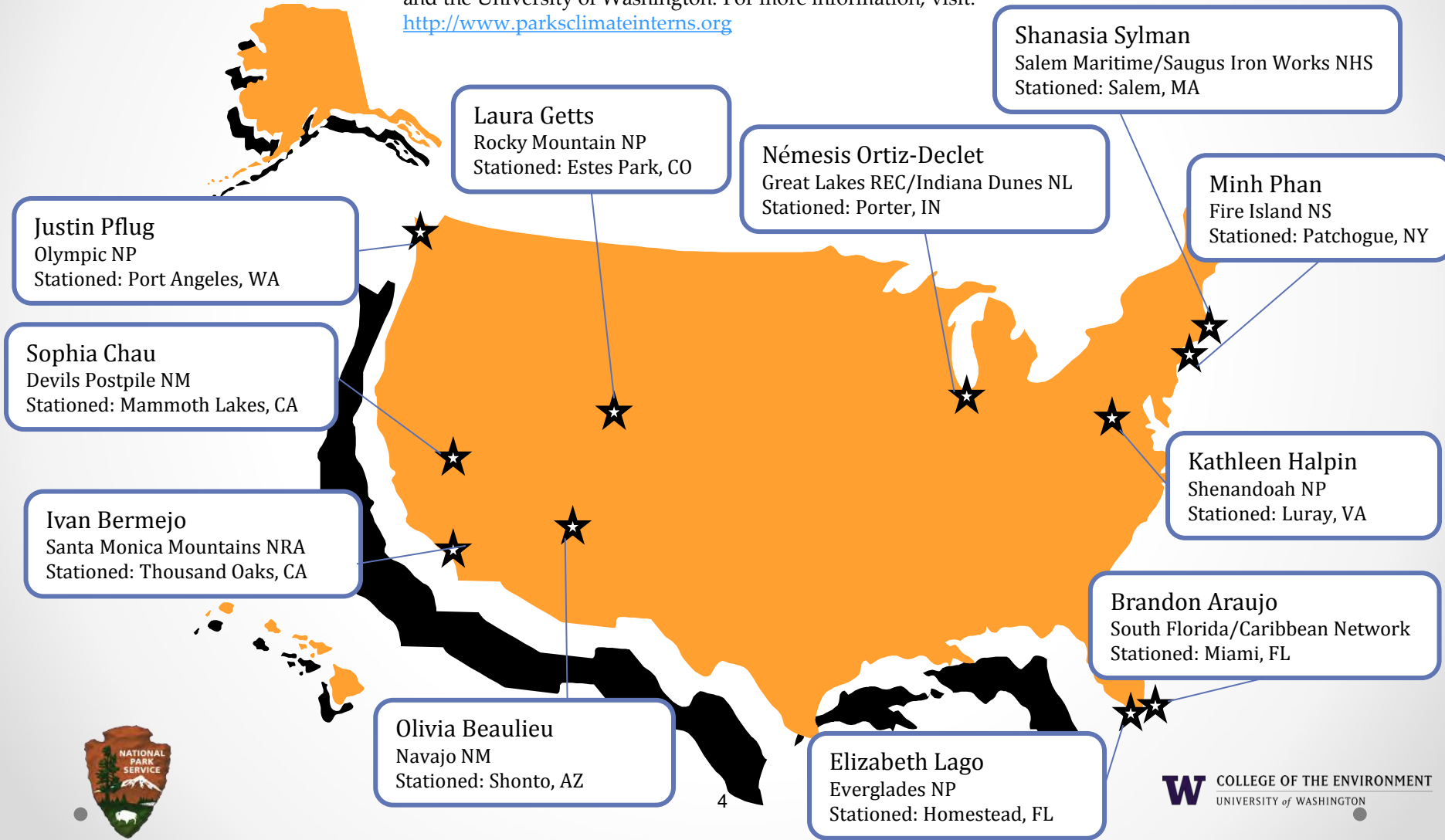
Contact Information

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2017 Young Leaders

The George Melendez Wright Initiative for Young Leaders in Climate Change is supported by the NPS Climate Change Response Program and the University of Washington. For more information, visit: <http://www.parksclimateinterns.org>



Region	Park Unit	First Name	Last Name	Project Title	Supervisor	University	Major/Program of Study	Expected Date	Current Academic Status
PWR	Devils Postpile NM	Sophia	Chau	What's Blooming in the Cold Air Pool?	Monica Buhler	Michigan State University	Fisheries and Wildlife	5/30/2022	Graduate Student (PhD)
SER	Everglades NP	Elizabeth	Lago	Changes in Roseate Spoonbill Colony Distribution	Elsa Alvear	Florida Atlantic University	Environmental Science	5/30/2019	Graduate Student
NER	Fire Island NS	Minh	Phan	Climate Change Science Communication in the Northeast	Elizabeth Rogers	East Carolina University	Geography/Atmospheric Sciences	5/17/2017	Recent M.S. Graduate
MWR	Great Lakes REC / Indiana Dunes NL	Nemesis	Ortiz-Declet	Identification, Inventory, and Characterization of Vernal Pools to Assess Vulnerability to Climate Change	Desiree Robertson-Thompson	University of Wisconsin	Water Resources Management	6/1/2019	Graduate Student
IMR	Navajo NM	Olivia	Beaulieu	Preserving Site Access and Cliff Dwellings in the Face of Arroyo Incising and Expansion	Greg Luna Golya	University of Minnesota	Earth Sciences	6/1/2021	Graduate Student (PhD)
PWR	Olympic NP	Justin	Pflug	Vanishing Ice. Understanding the Rate and Extent of Glacier Loss in the Olympic Mountains	Bill Baccus	University of Washington	Civil and Environmental Engineering	1/30/2022	Graduate Student (PhD)
WASO	Rocky Mountain NP	Laura	Getts	Establishing Long Term Monitoring Project for Pikas in Rocky Mountain National Park	Nathan Galloway	Plymouth State University	M.S. Environmental Science and Policy	8/31/2017	Recent M.S. Graduate
NER	Salem Maritime / Saugus Iron Works NHS	Shanasia	Sylman	Establish Climate Change Monitoring on Cultural Landscapes and Historic Structures	Gavin Gardner	Harvard University	Urban Planning	5/24/2018	Graduate Student
PWR	Santa Monica Mountains NRA	Ivan	Bermejo	Develop Models for Community-Based Dialogues about Climate Change in Los Angeles	Michael Liang	Hofstra University	Sustainability studies	12/1/2017	Senior
NER	Shenandoah NP	Kathleen	Halpin	Shenandoah Salamander: Climate Change Casualty or Survivor? Teacher Workshop	Tim Taglauer	Indiana University	Environmental Science, Secondary Education	12/18/2017	Graduate Student
SER	Caribbean Network	Brandon	Araujo	Reef Temperature Wrangler for South Florida National	Mike Feeley	University of North Florida	Psychological Science	4/17/2017	Recent M.S. Graduate

NPS George Melendez Wright Initiative for Young Leaders in Climate Change Cooperator: University of Washington College of the Environment P.I. Lisa Graumlich						Actual	
Task Agreement	Year 2: 2017-2018				Expenditures to date		Budget Balance
9/14/2016	Unit	Cost	Amount	Totals	9/1/16-8/31/17	as of 8/31/17	
Salaries:	# of months	Monthly \$	Project Salaries				
Director/PI							
Lisa Graumlich	0.15	\$ 25,347	\$ -	no cost			
Assoc. Director							
Stephanie Harrington	0.5	\$ 14,623	\$ -	no cost			
Administrator							
Adrienne Karpov	2.75	\$ 7,245	\$ 19,924		\$ 18,760		
Software Engineer							
Davina Spencer	0	\$ 8,342	\$ -	no cost			
Program Specialist							
Jenifer Moreland	1.5	\$ 6,273	\$ 9,410		\$ 5,136.00		
Total Administrative Personnel:			\$ 29,334	\$ 29,334	\$ 23,896		
Internship Salaries:	# of Interns	Hourly Rate	No. of Hours				
Total Internship salaries:	11	\$ 16.00	480	\$ 84,480	\$ 72,790		
(based on 12 weeks/40 hrs. per week/\$15 per hr = \$7200)							
Est. cost per intern plus benefits		9,055	\$ 108,656.64				
Total Salaries:				\$ 113,814	\$ 96,686	\$ 199,728	
Benefits:	Rate	07/01/2017					
Professional Staff	32.40%	32.5%	\$ 9,504		\$ 7,742		
Hourly staff (Interns)	17.90%	20.70%	\$ 15,121.92		\$ 15,068		
Total Benefits:			\$ 24,626	\$ 24,626	\$ 22,810	\$ 39,396	
Operations:	No.	rate	Amount				
Background Checks	11	\$ 81	\$ 891		\$ 890.00		
IT for database/web interface							
revisions/support		\$ 500	\$ -	no cost			
revisions JUMP App)	1	\$ 5,500	\$ 5,500		\$ 5,500.00		
Publications/Materials/Design			\$ 500				
Housing Stipend Fund	2	\$ 2,518	\$ 5,036		\$ 5,430.00		
Total Operations:			\$ 11,927	\$ 11,927	\$ 11,820	\$ 40,101	
Travel:	# of Students	Est. cost per trip					
Student project-supported travel	2	\$ 1,000	\$ 2,000				
Student Travel to Prof. Dev. Symp	11	\$ 1,500	\$ 16,500		\$ 8,322.00		
Student Travel to George Wright Society mtg.		\$ 1,000	\$ -		\$ 6,030.00		
Total Travel:			\$ 18,500	\$ 18,500	\$ 14,352	\$ 62,047	
Direct Costs:			\$ 168,866				
Indirect Costs: (Based on CESU negotiated rate)	idc rate:	17.50%	\$ 29,552				
TOTAL PROJECT COSTS:			\$ 198,418	\$ 145,668	\$ 341,272		

Attachment D Project Reports 1-11

Attachment D provides brief overview reports for each project. More detailed reports and additional deliverables are available upon request.

PROJECT REPORT

2017 George Melendez Wright Initiative for Young Leaders in Climate Change

Project Title	What's Blooming in the Cold Air Pool?
Author	Sophia Chau
Park	Devils Postpile National Monument

Supervisor: Monica Buhler

Overview

This report provides a summary of and recommendations for the citizen science program at Devils Postpile to monitor plant phenology within and outside of a cold air pool (CAP). The program seeks to better understand the biological response to CAPs, informing efforts to manage climate change refugia under climate change.

Problem Statement

Changing precipitation and temperature patterns in the Sierra Nevada have led to earlier spring snowmelt, drought, and shifting species ranges and phenology (timing of key life events)^{1,2,3}. These impacts will likely worsen⁴ and lead to species population decline and compromised wildlife habitat and natural resources. Cold air pools⁵ have the potential to maintain climate change refugia⁶, areas that are relatively buffered from modern climate change that enable the persistence of valued resources. Although much is known about the physical dynamics of CAPs, an understanding of the biological response to the cooler and moister conditions within CAPs is lacking.

Objectives

This project had the following objectives:

- 1) Determine whether plant phenology (timing of key life events such as fruiting, flowering, and senescence) can be used to understand and monitor a biological response to the cooler conditions within CAPs (Plant phenology has been identified as a key indicator for monitoring climate change because it is sensitive to temperature.),
- 2) Increase understanding of the physical dynamics of the CAP at Devils Postpile,
- 3) Link phenology monitoring to CAP monitoring,
- 4) Engage park visitors and volunteers in plant phenology monitoring and communicate to them climate change and its impacts on the region,
- 5) Improve the pilot citizen science plant phenology monitoring program at Devils Postpile, and
- 6) Communicate project findings to the NPS Climate Change Response Program, park staff, scientists, and the public.

Methods

To achieve the above objectives, the intern

- 1) Monitored the phenology of 3 individuals of 4 species—gray alder (*Alnus incana*), mountain pride (*Penstemon newberryi*), Lodgepole pine (*Pinus contorta*), and wax currant (*Ribes cereum*)—at several sites (57 total individuals) within and outside of the CAP at Devils Postpile on a weekly basis using protocol established by Nature's Notebook,
- 2) Downloaded and analyzed temperature data from sites within and outside of the CAP,
- 3) Linked plant phenology with temperature within and outside of the CAP,

- 4) Created outreach material including instructions, species-specific information on phenophases, and information on how to get involved,
- 5) Developed a set of recommendations and next-steps for the pilot citizen science plant phenology monitoring program at Devils Postpile, helped train Student Conservation Association (SCA) interns in plant phenology monitoring, and
- 6) Presented project significance and findings orally and in-writing to different audiences through multiple venues (YLCC 2017 Symposium, Soda Springs Meadow Management Workshop hosted by Devils Postpile, YLCC Project Report, personal blog).

Results

Although there was not a clear phenological response to the CAP, we observed a trend of later development within the CAP for eight out of fourteen phenophases. More evidence is needed to determine if plant phenology can be used as a biological indicator of cooler night-time temperatures in CAPs. No phenophases developed earlier within the CAP. Microclimate, photoperiod, and nutrient availability are variables aside from temperature that likely also influenced plant phenology. Further, the cooler night-time conditions within CAPs may be insufficient for eliciting a clear phenological response.

The CAP formed on all 30 days from 7/19/2017 to 8/17/2017. Night-time low temperatures in the CAP were significantly lower than out of the CAP ($p < 0.005$) and cooler by an average of 3.9°C. On average the CAP started to form at 7:30PM, reached its daily low temperature at 6:30AM, and began to dissipate at 7:30AM. Daily maximum temperatures in and out of the CAP were not significantly different ($p > 0.05$).

Due to the monument's delayed opening, citizen scientists were unable to participate in phenology monitoring this season. The current protocol is likely too complicated for citizen scientists to follow and could also be revised to potentially reveal a clearer phenological response to CAPs.

Recommendations

The following is a set of recommendations for improving the citizen science program:

- Use Project Budburst, a plant phenology citizen science program with simpler protocol than Nature's Notebook
 - Use "Y/N" for presence/absence of a phenophase or date of first observation instead of number and percentages (*e.g.*, number of fruits)
 - Record and download data through the BudBurst mobile app
- Omit phenophases that are difficult to monitor such as leaf size
- Monitor the most sensitive phenophases:
 - Ripe fruits in wax currant
 - Flowers in gray alder
 - Fruits in gray alder, mountain pride, and wax currant
 - Open pollen cones in lodgepole pine
- Monitor fewer species but with a greater sample size (6-8/site)
- Start monitoring earlier in the season and extend monitoring into the fall
 - *E.g.*, Monitor colored leaves in quaking aspen (*Populus tremuloides*)

N.b.: Species chosen for monitoring are constrained by the species and number of individuals present both within and outside of the CAP, and the timeframe for phenology monitoring is constrained by the monument's opening and closing dates.

Deliverables

1. Citizen Science Phenology Monitoring Program Fact Sheet
2. Citizen Science Phenology Monitoring Program Instruction Booklet
3. Phenophases Reference Sheets
4. Plant GPS Location, Aspect and Slope Reference Sheet
5. Temperature Logger Locations Map
6. Citizen Science Project Advertisements
7. Cold Air Pooling Summary
8. Phenology Monitoring Summary
9. Yosemite Hydroclimate Meeting Poster
10. Sophia's personal blog: sophianchau.wordpress.com
11. Project photos

Literature Cited

1. Hayhoe et al. 2004. Emissions pathways, climate change, and impacts on California. *PNAS*, 101(34):12422-12427.
2. Moritz et al. 2008. Impact of a Century of Climate Change on Small-Mammal Communities in Yosemite National Park, USA. *Science*, 322(5899):261-264.
3. Stewart et al. 2017. Apparent climate-mediated loss and fragmentation of core habitat of the American pika in the Northern Sierra Nevada, California, USA. *PLoS One*, 12(8):e0181834.
4. Cayan et al. 2008. Climate change scenarios for the California region. *Climatic Change*, 87(Suppl 1):S21-S42.
5. Lundquist et al. 2008. Automated algorithm for mapping regions of cold-air pooling in complex terrain. *J Geophys Res*, 113:D22107.
6. Morelli et al. 2016. Managing Climate Change Refugia for Climate Adaptation. *PLoS One*, 11(8):e015990.

PROJECT REPORT

2017 George Melendez Wright Initiative for Young Leaders in Climate Change

Project Title	Changes in Roseate Spoonbill Colony Distribution
Author	Elizabeth Lago
Park	Everglades National Park

Overview: Roseate spoonbill nesting data was collected from land managers and university researchers to map changes in their nesting distribution. The maps produced demonstrate spoonbill distribution beginning in 1936 when they were found nesting in Florida Bay. From then, roseate spoonbills have expanding their range inland with nesting appearing in Georgia in 2011 and 2014. These maps will be used in determining sea level rise as the cause of this expansion in distribution.

Problem Statement: Roseate spoonbills are an indicator species in Everglades National Park (ENP) and could be changing their distribution due to sea level rise. In 1936, roseate spoonbills nested primarily in Florida Bay, located inside Everglades National Park. In 1975, roseate spoonbills began nesting in Tampa Bay and have since continued to move locations that are northward and inland, including Biscayne National Park. Even with this change in distribution, roseate spoonbill numbers have been declining since 1979. Deeper waters around Florida Bay could be causing roseate spoonbills to move inland to find shallow waters where concentrations of fish will be high.

Objectives of the project: Data had to be collected from land managers in Florida and Georgia. This data ranges from 1936 – 2016 and includes nest coordinates and nest numbers. This data was to be mapped in GIS to show changes in distribution for different time periods.

Approach/method used to accomplish the objective: First, each separate nesting location was mapped for every year. The icon size at each location shows the number of nests in that location for that year. Second, nesting colony locations were grouped into regions and a center coordinate was calculated for each. Second, we summarized nest data into 10- and 5-year maps. To summarize multiple years into one map, total number of nests found in one location during the defined time period were added and divided by the number of times surveyed within those years. The averages of these locations were then added by region and divided by the number of locations in that region.

Results of the Internship: The intern successfully collected data from land managers from parks and universities, created an appropriate database to work with GIS, and successfully created maps using ArcGIS showing changes in distribution of roseate spoonbills.

Recommendations: When looking through EVER and BISC servers, I realized there were no GIS maps with hydrological and water quality conditions, although the data does exist.

Deliverables:

- a) ArcGIS maps demonstrating changes in roseate spoonbill distribution
- b) These maps are also available in a .lyr form that can then be mapped with other GIS layers

PROJECT REPORT

2017 George Melendez Wright Initiative for Young Leaders in Climate Change

Project Title Author Park	Northeast Region Science Communication Young Leaders in Climate Change Internship Minh Phan Fire Island National Seashore
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Overview

The Northeast Region (NER) Science Communication Network/Young Leaders in Climate Change Intern coordinated four monthly webinars to share post-Hurricane Sandy science conducted at coastal national parks. In addition, the intern worked with park staff and scientists to share research and monitoring outcomes through four web articles and 20 accompanying social media posts.

Problem Statement

Climate change, and specifically projected sea level rise and increased storm impacts, poses a significant challenge to protecting the natural and cultural features of coastal national parks in the Northeast. It is critical that the information collected through post-Hurricane Sandy studies of these coastal parks is available to park staff and to the public, to ensure informed decision making into the future.

Objectives

The objectives of the NER Science Communication Network Internship project were to expand and enhance science communication efforts at coastal parks with a focus on post-Hurricane Sandy research; and, cultivate a sustainable network of researchers, resource managers, and communicators who can work together to better communicate park science.

Approach

Post-Hurricane Sandy research and communication successes were shared on three NER Science Communication Network webinars throughout the summer. Participants also shared insight into improved science communication efforts, and information for the development of Sandy-focused science communication products, by telephone and email and during in-person interviews. Minh Phan, the NER Science Communication Network Intern, coordinated calls and developed science communication products with guidance from Elizabeth Rogers and Amanda Babson. During his internship, Minh was stationed at Fire Island National Seashore and visited Cape Cod National Seashore and Gateway National Recreation Area to connect with park and program staff, and park partners.

Results

Minh successfully completed the development of digital science communication products focused on post-Hurricane Sandy research at coastal parks in the Northeast. He also coordinated four monthly calls and helped developed recommendations to sustain and expand the new NER Science Communication Network.

Recommendations

Recommendations include the coordination of NER coastal parks on a 5-year Hurricane Sandy anniversary social media campaign and, potentially, a multipark science conference. Recommendations for the expansion of the network and continued improvement of science communication in the NER are included in the attached project report on pages 4 and 5.

Deliverables

- Four web articles (attached)
- Social media posts (included in attached draft social media campaign)
- Recommendations (included in attached project report)

PROJECT REPORT

2017 George Melendez Wright Initiative for Young Leaders in Climate Change

Project Title	Identification, Inventory, and Characterization of Vernal Pools to Assess Vulnerability to Climate Change
Author	Nemesis Ortiz
Park	Indiana Dunes National Lakeshore

Abstract:

Vernal pools are small, ephemeral wetlands that provide critical habitat for many types of invertebrates and amphibians. Changes in precipitation patterns and temperature trends will likely affect vernal pools. To assess their vulnerability to climate change, we identified, inventoried, and characterized vernal pools at Indiana Dunes National Lakeshore.

Problem Statement:

- Due to their seasonal nature and variability, vernal pools are difficult to detect through field surveys alone. Remote sensing methods have been developed to detect the presence of vernal pools by using ground elevation and water presence/absence data. How accurate are these methods in detecting vernal pools at INDU?
- Vernal pools change in volume in response to varying weather patterns. With expected changes in precipitation frequency and intensity and temperature trends due to climate change, vernal pools are at risk of either becoming more established permanent wetlands or drying up. What characteristics make vernal pools resilient to climate change?

Objectives:

- Test the accuracy of the remote sensing detection method by conducting field surveys.
- Develop maps and an inventory of vernal pools located in the upland area of the Cowles Bog unit of INDU.
- Establish defining characteristics of INDU vernal pools and
- Develop a database with the characteristics of the identified vernal pools to compare how these influence their tendency towards climate change resilience.
- Promote monitoring of abiotic and biotic data in vernal pools during the spring.
- Promote long-term monitoring for assessing which vernal pools are more resilient than others to climate change.
- Promote the development of a citizen science vernal pool monitoring program in INDU.

Methods:

Field verifications were conducted using remote sensing methods to identify potential vernal pools in the Cowles Bog unit of INDU. We recorded vernal pool locations and created maps based on GPS data. Vernal pools were distributed into four distinct clusters, which we designated Clusters 1, 2, 3, and 4. We documented locations of permanent wetlands, as well as potential

inlets and outlets of vernal pools. Photos and information regarding hydroperiod, vegetation, and other observations were taken.

We compared precipitation data for the dates of the satellite images used to detect potential vernal pools with precipitation data for the field verification period.

Data regarding area, depth, percent canopy cover, slope, and presence of invasive species were collected. Plant surveys were conducted to identify common species among the vernal pools and any potential indicators. A soil profiling method was uniquely developed for this project to identify hydric soils and rank soil quality according to wetland standards.

Results:

The remote sensing detection method identified 20 potential vernal pools for the Cowles Bog unit, whereas field surveys identified 31. Of the 31 vernal pools identified in the field, 15 were detected by the remote sensing method and 16 were not detected (omission errors). The remaining potential vernal pools detected yet not identified in the field (commission errors), were determined to be permanent wetlands, or other geologic formations.

Satellite images used to develop the remote sensing method were collected from different years, which consequently affected the water presence/absence analysis used to detect vernal pools.

Among the four vernal pool clusters, area and depth were variable, but not statistically significant. Some plant species were similar among all clusters, including an indicator species of nettle. Cluster 4 had the lowest ranked soil quality. Cluster 3 had the highest invasive species presence, whereas Cluster 1 had no visible invasive species present. Cluster 1 had the highest range of canopy cover percent. Long-term monitoring may provide an insight to which vernal pools are more resilient than others.

Recommendations:

- For more accurate vernal pool detection results from the remote sensing method, satellite imagery for the same year, during different seasons, should be re-analyzed.
- Collection of data should continue on an annual basis to identify significant differences to determine resiliency of individual vernal pools to climate change.
- Photostations should be established and a monthly photographic record maintained.
- Weekly hydroperiod data (area and depth) should be collected after rain events to study the effects of varying weather patterns on each vernal pool. Two clusters may be surveyed per day.
- Detailed hydrologic models should be developed to assist in identification and characterization of vernal pools in INDU.
- Invasive species presence in vernal pools should be studied, monitored, and mitigated to reduce the vulnerability of these small wetlands.

- Inventory of amphibians and aquatic invertebrates should be conducted during the Spring.
- Detailed soil analysis should be conducted to develop soil profiles for each vernal pool.
- Percent canopy cover should be collected for each vernal pool, results should be considered for tree clearing management implications.
- Fire regime impacts on vernal pools should be assessed.

Deliverables:

- Map of the verified vernal pools vs. the detection method potential vernal pools in the Cowles Bog Site
- Map of the Cluster 1 Verified Vernal Pools in the Cowles Bog Site
- Map of the Cluster 2 Verified Vernal Pools in the Cowles Bog Site
- Map of the Cluster 3 Verified Vernal Pools in the Cowles Bog Site
- Map of the Cluster 4 Verified Vernal Pools in the Cowles Bog Site
- Oral presentation of the Cowles Bog Vernal Pool Project during iSWOOP workshop
- Oral presentation of the Cowles Bog Vernal Pool Project during Brown Bag Lunch
- Identification, Inventory, and Characterization of Vernal Pools to Assess Vulnerability to Climate Change Internal Report
- Cowles Bog Trail Vernal Pool Characterization Database

PROJECT REPORT

2017 George Melendez Wright Initiative for Young Leaders in Climate Change

Project Title	Documenting arroyo incision and expansion at Keet Seel Canyon associated with climate change and flood events
Author	Olivia Beaulieu
Park	Navajo National Monument

Overview:

Climate change is causing arroyo incision and expansion to occur at a much faster rate in Keet Seel Canyon. To investigate the changes in the canyon, I focused on two main goals for this summer: 1) to document and monitor the ongoing erosion and deposition, and 2) to reconstruct the 2011 flood.

Problem Statement:

Keet Seel Canyon is being affected by the changing climate. The southwest is trending towards a hotter and drier climate (Block and Hiza Redsteer, 2011). Increasing temperatures, earlier snowmelt, and decreasing peak streamflows are been observed throughout the southwest (Block and Hiza Redsteer, 2011). Higher temperatures mean more evaporation which leads to more intense precipitation events and these can affect river flows (Stromberg, Lite, and Dixon, 2010). Small changes in precipitation in arid and semiarid regions lead to large changes in surface runoff (Dahm and Molles, 1992). This all leads to more erosion of fluvial terraces, which is putting archaeological sites in danger of being swept downstream.

Objectives:

This project aimed to better understand the changing morphology of Keet Seel Canyon. Climate change is causing more intense precipitation events to occur in the Southwest, which, in turn, causes sediment to be eroded more quickly within the canyon. We focused on a 4km reach of the canyon, from upstream at Keet Seel ruins to downstream at the big waterfall. A perennial river runs through the canyon from northeast to southwest. This is a dryland river and is very susceptible to changes in precipitation in the region. Our two main goals to help better understand the river and how climate change is affecting the canyon was to document and monitor erosion and deposition within the canyon and to reconstruct the 2011 flood that drastically changed the morphology of the river. Documenting and monitoring of erosion was done by repeat photography. Reconstructing the 2011 flood was accomplished by collecting coordinate measurement data using a total station and modeling the flood flow in HEC-RAS, a program that models the hydraulics of water flow through natural rivers.

Methodology:

Multiple approaches were used to reconstruct the 2011 Keet Seel Canyon flood and qualitatively observe erosion and deposition within the canyon. We conducted field work, looked at historical photographs, interviewed park staff, and modeled flood flows within the

canyon. Historical photographs and photographs taken before the 2011 flood were shared by the rangers. Using repeat photography, we are able to take photos this summer and match them to photos taken in 2007, 2010, and 2011. In these matches, we observed arroyo cutting, incision, and aggradation in the canyon. We used a total station to collect coordinate measurements in cross sections throughout the canyon. Four cross sections were taken downstream from the location of the log that was deposited in the 2011 flood and a single cross section was taken just above the big waterfall. Cross sections were taken in these locations because we knew the height of the 2011 flood in those areas. We modeled the cross sectional data and was able to estimate the discharge of the flood. From this discharge value, we could calculate the recurrence interval of this flood using StreamStats.

Results:

We successfully repeated multiple photographs to document erosion and deposition taking place in the canyon. These repeated photographs (attached as a deliverable) show the drastic changes occurring within the canyon. I was able to repeat ten different photos located in my study area. Six of the photos were originally taken in 2007, three were taken in 2010, and one was taken in 2011 (before the 2011 flood). Each photo shows a varying degree of erosion or deposition.

We were also able to reconstruct the 2011 flood that ripped through the canyon. Using coordinate measurements collected from a total station, we modeled the flood flow in HEC-RAS. From the five cross sections we measured, we created two models. Our first model, by the log perched on the rock, determined the discharge to be approximately 7,400 cubic feet per second (cfs), however, we believe this to be a relatively high estimation due to the resolution of the cross sectional data. The second model, located above the big waterfall, determined the discharge to be approximately 2,500 cfs. We used this discharge value to calculate the recurrence interval of the flood using StreamStats. This flood is believed to be between a 100- and 500-year flood event.

Recommendations:

There is much work left to be done in Keet Seel Canyon to accurately understand the impact climate change is causing. Yearly light detection and ranging (LIDAR) surveys will provide detailed topography of the canyon and changes over time in the canyon will be more easily observable. LIDAR combined with satellite imagery produces an overview of Keet Seel Canyon that presents the ongoing changes occurring within the canyon. Coring trees and dating the tree-rings will provide information on the changing climate and precipitation (Fritts and Dean, 1992). Hopefully, these records go as far back as the habitation of Keet Seel in the 1200s. Obtaining accurate dates for the soil formations in the canyon will help reconstruct the incision and aggradation cycles, which can be correlated with climate, precipitation, and water table levels. *In situ* approaches can lessen the impact of storms within the canyon system. Revegetation in the canyon will help stabilize stream banks and slow down arroyo cutting (Block

and Hiza Redsteer, 2011). Barriers to trap sediment would help terraces aggrade. The combination of the two will help decelerate incision due to extreme flooding events that may become more prevalent in the future due to climate change.

Deliverables:

- a. Matched repeat photographs
- b. Short detailed report
- c. HEC-RAS Model
- d. Streamstats spreadsheet for recurrence intervals
- e. Pechu Kucha Presentation

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PROJECT REPORT

2017 George Melendez Wright Initiative for Young Leaders in Climate Change

Project Title	Vanishing Ice, Understanding the Rate and Extent of Glacier Loss in the Olympic Mountains
Author	Justin Pflug
Park	Olympic National Park

Olympic National Park in Northwest Washington is home to one of the most unique groupings of glaciers in the world. This project utilizes remotely-sensed products and modeling techniques to better understand rate and magnitude of glacier loss and the downstream water released by these frozen reservoirs.

Problem statement

Due to their low-latitude, low-elevation, temperate climate, and precipitation-dominant location, the Olympic Mountains hold some of the most sensitive glaciers in the world [1]–[3]. Glacier persistence depends on adequate snowfall and limited insolation. However, future climate predictions for this region describe sufficient temperature increases to shift snow precipitation to rain, depleting sources of ice and exposing glaciers to melt during the summer period [1], [2], [4]–[7]. Although the extent and presence of glaciers are now easily measurable using remote-sensing techniques, the impacts of climate change on downstream resources are highly uncertain and not easily measured or observed.

Objectives

Collection of multiple remotely-sensed products throughout WY2015 provided a unique opportunity to analyze glacier extent change in the Olympic Mountains and the downstream water contributions from this change. WY2015 was an abnormally warm period with conditions similar to future climate-change predictions for the Pacific Northwest [5], [7]. 2015 glacier extents were compared to past glacier surveys to analyze the amount and rate of loss since 1982 and 2009. With extent analysis completed, Light Diffraction and Ranging (LiDAR) and meteorological data were used with a variety of models to estimate the amount and expected timing of water released from glacier ice.

Upon the completion of this project, glacier outlines and mass-balance estimates will become available to the NPS, the scientific community and the general public to provide information on the current ice loss in Olympic National Park and provide a baseline to which future glacier surveys will be compared. The modeling component of this work will also define the best method in which to model glacier stream contribution in the future for Olympic National Park and Pacific Northwest watersheds.

Methods

This project was broken into three sections: glacier delineation, long-term mass-balance estimation, and downstream glacier contribution.

Glacier delineation was performed by manually outlining all Olympic National Park glaciers and ice patches identifiable by 2015 NAIP imagery. Glacier polygon vertices were located 2-7 meters apart (depending on topography and variations in glacier shape) and LiDAR was used to estimate glacier extents in locations where shadows were prominent. Uncertainty was defined by three products including a minimum, maximum, and middle outline to estimate the visible ice extent, potential maximum extent, and best guess respectively.

Long-term mass-balance was estimated using LiDAR collected in September 2014 and March 2016. Due to collections occurring during a “snow-free” and “snow-present” phase, an algorithm was developed to isolate the change on ice surfaces by observing the snow depth differences surrounding the glacier.

Downstream glacier contribution was performed by different modeling approaches including a physical hydrologic model that explicitly accounts for glaciers (SnowModel) and an empirical Positive Degree-Day (PDD) model that relates temperature to summer glacier melt.

Results

Glacier delineations determined a loss of 36 glaciers and an 18% reduction in surface area since 2009. Interestingly, this shows that the rate of recession from 1900-1980 doubled from 1980-2009 and nearly quadrupled from 2009-2015. It is important to note that this final elevated recession rate is likely driven by the abnormally warm 2015 water year. However, analysis of snow-free reaches of major glaciers in WY 2013, also showed recession is accelerating slightly.

Mass balance results showed that glaciers lost over 35 million cubic meters of water during the 2015 melt season. This is approximately four times the amount of loss that occurred for a similar period in the Canadian Rocky Mountain Range, demonstrating the increased vulnerability of Olympic’s glaciers. The above results are for glaciers greater than .01 square kilometers in order to exclude perennial snow/ice patches and provide consistency between previous reports and procedures recommended by the World Glacier Inventory [1], [3], [6].

New delineations and mass-balance estimates also allowed for the calibration of models for the analysis of daily glacier-loss and downstream contribution. I am now continuing on this work which will culminate as a Master’s Thesis at the University of Washington (Winter 2018).

Recommendations

Considering the downstream impacts on a number of fragile ecosystems, glacier-water contribution should be a paramount concern in Olympic National Park and the National Park Service. With climate change progressing, it is likely that no glaciers outside of the Mount

Olympus massif will survive past 2100 [1]. It is therefore important to relate glacier extents and location to water resources and the large ecological impact that will result from the depletion of glaciers.

With the conclusion of modeling, I hope to create an easily utilized framework that can be used annually to observe downstream water resources. This framework could provide a continuous multi-year observation of downstream water resources to help Park Service staff and researchers better understand the effect that the glacier recession may have. Understanding the limitations of modeling, I would also urge that an upstream, near-glacier stream gauging station be installed, in order to reduce modeling error and more explicitly define glacier contributions.

In addition, surface elevation surveys and traditional glacier ablation stake measurements should continue with as much thoroughness as funding allows. This is key to understanding annual fluctuations in mass balance.

Deliverables

2015 glacier delineations: MIN, MID, and MAX delineations in shapefile format.

Digital Elevation Models for all major Olympic Mountain Glaciers (derived from LiDAR).

Modeling Framework: To be determined. In the process of finding the most accurate/efficient method. Will provide this framework upon the completion of my Masters thesis.

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PROJECT REPORT

2017 George Melendez Wright Initiative for Young Leaders in Climate Change

Project Title	Pikas in Peril: A citizen science program for American pika long-term population monitoring and habitat projections in Rocky Mountain National Park
Author	Laura Getts
Park	Rocky Mountain National Park

Supervisor: Nathan Galloway, Disease Ecologist, NPS Biological Resources Division

Overview: A long-term citizen science monitoring program was established in Rocky Mountain National Park to better track projected changes and evaluate climate-driven model predictions of American pika occupancy in Rocky Mountain National Park.

Problem Statement: The American pika (*Ochotona princeps*) has been identified as a sentinel of climate-change impacts within the National Park System (NPS), prompting recent projections of pika vulnerability across eight park units. Dramatic declines in pika occupancy were projected for Rocky Mountain National Park (ROMO), with most occupied pika habitats expected to become vacant during this century, even under moderate projections for climate change. NPS managers have limited resources, yet require additional information to help them adequately predict and prepare for changes to the ecosystems within NPS units. As sentinels of climate-change, pika may be one of the most valuable sources of information about natural resource health in a changing climate.

Objectives: Use citizen scientists to generate long-term monitoring datasets for the American pika in ROMO to track projected changes and evaluate model predictions for pika occupancy. Production of high quality, long-term data on American pika occupancy can inform and help prepare NPS managers for changes to NPS ecosystems.

Approach: Development of a long-term citizen science monitoring program that uses volunteers to consistently obtain data at designated plots throughout the park, year after year. Volunteers are trained to implement a data-rich, yet user-friendly protocol that captures variables that are key to understanding trends in pika populations. Successful recruitment, training, and maintenance of a committed and informed volunteers base will be critical to the program's success.

Results: Throughout the 2017 field season, 23 volunteers were successfully trained in pika monitoring, contributing more than 300 volunteer hours to the park. In total, 33 plots were visited, and 19 plots were successfully surveyed. Of these plots, 9 exhibited fresh sign of pika, 7 exhibited old sign of pika, and 3 exhibited no sign of pika. Three plots from the 2010 – 2012 PiP study were resurveyed in 2017. Two of these plots showed fresh sign of pika in both 2010 and 2017, while one of these plots showed fresh pika sign in 2011 and old pika sign in 2017.

Recommendations: We recommend that the project hire or recruit an official ROMO Pikas in Peril coordinator for 1 or 2 more seasons to solidify volunteer investment, expand the volunteer base, broaden training opportunities, and pilot new technology. In the immediate term, ROMO should facilitate participation of current volunteers by establishing a centralized materials hub, and clarifying sign-up and data entry procedures. The park should also utilize the East and West-side Volunteers in Parks offices to expand volunteer recruitment and participation. Finally, we recommend participation in

the new, statewide, Colorado Pika Project initiative, and continued communication with partner organizations, such as the Front Range Pika Project, which is a valuable source of information and volunteer resources.

Deliverables: See *Rocky Mountain National Park Long-Term Pika Monitoring Program Materials and Review*.

PROJECT REPORT

2017 George Melendez Wright Initiative for Young Leaders in Climate Change

Project Title	Climate Change and Historic Preservation: Monitoring Derby Wharf at Salem Maritime NHS
Author	Shanasia Sylman
Park	Salem Maritime National Historic Site / Saugus Iron Works National Historic Site

Overview

Development of monitoring strategy proposals, ranging in complexity and community involvement, that utilized citizens science methods for documenting the vulnerability of Derby Wharf to climate change impacts at Salem Maritime NHS.

Problem Statement

Salem Maritime is a coastal urban park with several historic buildings and wharfs along a tidal harbor. One wharf, Derby Wharf, has been identified (through observation and preliminary assessment) as the most vulnerable asset to current environmental conditions as well as projected future conditions from climate change impacts identified for the region. There are questions about the extent to which Derby wharf is vulnerable, how often it is impacted, and how vulnerability varies across the structure. A goal has been set to address these unknowns by better documenting the status of the wharf over time, while considering the limited number of staff and the park's interest to engage the community on this issue.

Objective

Craft a manageable and replicable monitoring strategy that uses citizen science methods to answer questions, address concerns and inform future decisions for the repair, maintenance and resilience of Derby Wharf, as a means of engaging and educating the community on climate change issues in Salem Maritime NHS.

Methods

-
- Understand the historic and modern significance of the park
 - Assess current and future environmental stressors for the site
 - Acquire NOAA tidal data and trends for Salem Harbor
 - Research the structural history and current structural characteristics of Derby Wharf
 - Determine information deficiencies for Derby Wharf and its local environment
 - Identify pertinent questions about the vulnerability of Derby Wharf to current environmental conditions
 - Research monitoring methods used for sea level rise and/or coastal structures similar to Derby Wharf and how the public can be incorporated
 - Develop strategies that address the needs of Derby Wharf, Salem Maritime park staff and the greater Salem community specifically

Results

Documentation of the historic relationship between Derby Wharf and Salem Harbor has been assembled. Pertinent questions about current conditions of Derby Wharf have been developed and protocols for the proposed monitoring strategies to address these questions have been drafted.

Next Steps

-
- The monitoring protocols will need to be reviewed by current staff.
 - A runthrough of the protocols will need to be conducted as a method of revision.
 - Findings from the upcoming professional engineering survey of Derby Wharf shall be incorporated and used to update supporting documents.
 - Public engagement and training materials would then need to be drafted and ready for distribution by the next summer season.

List of Deliverables

-
- Background Report
 - Draft of Photographic Monitoring Protocol
 - Draft of Wharf Inventory Protocol

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-
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PROJECT REPORT

2017 George Melendez Wright Initiative for Young Leaders in Climate Change

Project Title	Develop Models for Community-Based Dialogues about Climate Change in Los Angeles
Author	Ivan Bermejo
Park	Santa Monica Mountains National Recreation Area

Overview

The purpose of the internship was to create facilitated dialogue tracks focused on climate change through the needs and perspectives of community members in Los Angeles.

Problem Statement

Climate change in Southern California will disproportionately affect communities of color and low-income communities. How does Santa Monica Mountains National Recreation Area support and empower communities to address climate change on their own terms, rooted in their needs and values?

Objectives of the Project

The intern will engage with urban communities in Los Angeles to connect climate change to pressing community issues, such access to healthcare, clean water, safe public spaces, and public transportation. The intern will help develop dialogic programming that is replicable and relevant to community needs.

Approach/method used to accomplish the objective

In addition to local seasonal training, the intern attended “Forging Connections through Audience-Centered Experiences” at the Mather Training Center in Harpers Ferry, WV. Following the training, the intern reached out to local organizations in Los Angeles that could host and benefit from a community-based dialogue session around climate change. The intern then created a set of dialogic arcs that tied climate change with a social issue important to a local community. These dialogues were conducted in spaces such as the Los Angeles Public Library, Los Angeles State Historical Park, and local high schools. Towards the end of the internship, the intern created a “how to” document for recreating these dialogues.

Results of the internship

With a better understanding of the concerns and priorities of local communities, the intern created a series of audience-centered products and replicable programs that will benefit the park’s programming beyond the length of the internship. Dialogues also positively benefitted the community participants, as their discussions and solutions are self-generated and personally relevant.

Recommendations

One of my biggest recommendation would be consistency. In order to build strong ties with community members, there needs to be a consistent amount of interactions. I would highly recommend monthly meetings with organization that we interacted with during the summer.

Another step I recommend would be to be to continue social interactions with marginalized communities. Do NOT expect that communities should come to you; rather, the park should reach out to these communities.

Deliverables

- 5 “Report back” documents on Community Dialogues
- Dialogue self-evaluation template
- “A Young Leader in Climate Change Internship: Navigating Community-Based Dialogues on Climate Change” How-To Guide
- Community-Based Dialogue Tracks

Works cited, where applicable

All citations can be found within the “Young leader in Climate Change Internship: Navigating Community-Based Dialogues on Climate Change”

PROJECT REPORT

2017 George Melendez Wright Initiative for Young Leaders in Climate Change

Project Title	Shenandoah Salamander: Climate Change Casualty or Survivor?
Author	Kathleen Halpin
Park	Shenandoah National Park

Overview:

The goal of this project was to write a curriculum using the endangered Shenandoah salamander to communicate the localized impacts of climate change. The curriculum explores climate change at Shenandoah National Park, and the science of climate change. I recommend this curriculum be available online for any teacher to use.

Problem Statement:

For the residents and students of Virginia, the impacts of climate change (disappearing glaciers, dying polar bears, etc.) seem far away. However, the federally endangered Shenandoah salamander may also become extinct due to changing conditions on the highest peaks of Shenandoah National Park. By using this local example to communicate the potential negative impacts of climate change, local area teachers can teach their students about climate change and the importance of reducing their own carbon footprints.

Objectives:

The main objective of this project was to develop a series of lesson plans about climate change and the possible impacts of climate change on the endangered Shenandoah salamander. The lessons were to include background information on the Shenandoah salamander, about the causes and impacts of climate change, and participation in a ranger-led program at Shenandoah National Park about assessing appropriate salamander habitats and predicting how climate change might impact the Shenandoah salamander. Upon the completion of the curriculum, the second objective was to present and teach these lesson plans to a group of 25 local area teachers at a 2-day teacher workshop. A third objective was to present the latest climate change research at the teacher workshop to inform the teachers about climate change, and brainstorm how to address climate change in the classroom. Finally, the last objective of this internship was to synthesize the content for a climate change webpage for Shenandoah National Park. This webpage would communicate climate change information, including predictions for localized impacts of climate change in Shenandoah National Park.

Approach/methods used:

My approach for accomplishing these objectives was to work in tandem with Teacher-Ranger-Teacher Cassi Weathersbee to first design the new lesson plans. While redesigning and writing the content for the lessons, we worked with the concessioner for Shenandoah National Park to secure a conference room, lodging, and meals for the teachers during the teacher workshop. We also communicated with the teachers directly so that they knew what to expect at the workshop itself. During the workshop, our approach was for me to do a presentation on climate change for the teachers, and then to walk them through the Shenandoah salamander curriculum. The next day, Cassi led the teachers through another curriculum about how Shenandoah National Park treats its wastewater before releasing it back into the

watershed. We both led the on-site programs for both curriculums, so as to minimize the impact of this large group on the natural resources at Shenandoah National Park. My approach for accomplishing the climate change webpage was to model the existing climate change webpages on other National Park websites, but to address potential impacts that may be seen at Shenandoah National Park specifically.

Results:

Cassi and I designed one before-visit activity utilizing a video about the plight of the Shenandoah salamander, and prompting students to do their own research to compare the endangered salamander with the more common Eastern red-backed salamander. We kept the on-site visit as is, but ran through the procedure several times to update and tweak the directions as needed. Finally, we synthesized four different post-visit lesson plans which allow the students to analyze the data they collected during the on-site visit, create a social media campaign about climate change and the Shenandoah salamander, calculate and discuss their own carbon footprints, use computer simulations to learn about the greenhouse effect, and interpret real climate data and an infographic about carbon dioxide inputs and outputs in the atmosphere. We then co-organized a teacher workshop where we walked 25 local teachers through this and another curriculum about wastewater treatment. At this workshop, I also gave a 20-minute presentation, followed by a 20-minute discussion about climate change. Finally, I wrote the content for a climate change webpage for the Shenandoah National Park website.

Recommendations:

The park should continue to present this Shenandoah salamander lesson plan to local area teachers. The Education Office at Shenandoah National Park regularly offers teacher workshops to introduce local teachers to on-site programs, and this lesson plan should be included in these teacher workshops. The Shenandoah salamander lesson can be presented to the teachers in one day, including a full run-through of the on-site program. In addition, my biggest recommendation is to make this curriculum available on the Shenandoah National Park website. By making this curriculum available to everyone, rather just teachers that have participated in a teacher workshop, more people will be exposed to the connections between the endangered Shenandoah salamander and climate change. Furthermore, savvy teachers can use this curriculum as a model for demonstrating climate change impacts in their own backyards, regardless of how far they live from Shenandoah National Park. For example, a teacher in the state of Indiana could use these lesson plans, but tailor them towards conversation about climate change impacts on the endangered and beloved swamp rabbit in southern Indiana.

Deliverables:

“Shenandoah Salamander: Climate Change Casualty or Survivor?” lesson plans

“Shenandoah Salamander: Climate Change Casualty or Survivor?” web links page for lessons

Teacher workshop expanded agenda

Climate change webpage content

PROJECT REPORT

2017 George Melendez Wright Initiative for Young Leaders in Climate Change

Project Title	Reef Temperature Wrangler
Author	Brandon Araujo
Park	South Florida Caribbean Network

Overview

This project investigates coral bleaching by analyzing an extensive data set of water temperature and coral bleaching records collected by the South Florida Caribbean Network (SFCN).

Problem statement

Recently we've been losing a frightening amount of the world's coral reefs. Eighty percent of the reefs in the Caribbean (Gardner, Cote, Gill, Grant, & Watkinson, 2003), and over 50% in the Indo-Pacific region have already been lost (Bruno & Selig, 2007; De'ath, Fabricius, Sweatman, & Puotinen, 2012). The primary cause of this large decline in coral is coral bleaching.

Project objectives

The primary objectives of this internship, as stated in the position announcement, were to "correlate temperature readings between sites, fill data gaps, and report on trends at both a local and regional level." Additional objectives that were completed include: forecasting water temperature and coral bleaching, and comparing the reef depth temperature (RDT) data that is collected by SFCN with the National Ocean and Atmospheric Administration's (NOAA) sea surface temperature (SST) data.

Method

This project was primarily conducted using the open source statistical software "R." Multiple packages included in this software were used to impute missing data,

conduct trend analyses, create water temperature forecasts, quantify the relationship between water temperature and coral bleaching, predict coral bleaching, and compare RDT and SST.

Results

Water temperature trend analyses revealed a $.027^{\circ}\text{C}$ increase in water temperature per year since 1988 for the U.S. Virgin Islands. Despite this long-term positive trend, forecast models expect water temperatures for the summer of 2017 to remain below the bleaching threshold. This result suggests lower levels of coral bleaching than in previous years because water temperature accounts for 76% of the variance in coral bleaching at the monitoring sites around the Virgin Islands. By projecting this relationship between water temperature and coral bleaching onto the water temperature forecast for 2017, it can be estimated that 22% of the Virgin Islands monitoring sites will experience bleaching. Lastly, SFCN's reef depth temperature data were compared with NOAA's sea surface temperature data, revealing that SST tends to be cooler than RDT, with an average absolute difference of $.253^{\circ}\text{C}$. However, SST is still a significant predictor of coral bleaching, accounting for 75% of its variance.

Recommendations

The results of this project can be used to enable adaptive resource management for monitoring projects. In order to do so, these predictive models should be reassessed every year to enhance their accuracy. Also, future efforts should be made to increase the frequency of coral data collection in order to enable comparisons of bleaching across multiple sites to identify factors that moderate the relationship between thermal stress and bleaching. The influence of variables that are controllable (e.g., boating traffic, pollution,

etc.) may be especially important since any controllable effects that are found could be used to implement new policy decisions, such as the designation of marine protected areas, which have been shown to increase coral reef resilience (Mellin, Aaron, Cheal, Emslie, & Julian, 2016; Selig & Bruno, 2010). This project can also be used to start conversations with the public about why coral reefs are important, what their future looks like, and how individuals can help address the problem of coral bleaching.

Deliverables

1. Final Report
 - a. Outlines all of the work that was done during the project and includes the water temperature and coral bleaching forecast models.
2. Imputation Procedure
 - a. Step-by-step procedural outlining how to use R to impute missing data.
Also includes all the necessary R scripts and a training data set to practice on.

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