Adaptation to Climate Change and Monitoring of Ecosystem Services in the Cordillera Blanca, Peru

INTRODUCTION

Between June 1 and December 31 of 2014, researchers and volunteers with the American Climber Science Program conducted a set of scientific research projects in Huascaran National Park in the Cordillera Blanca, Peru. The objectives of this ongoing research are to better understand how mountain environments function and how those functions are changing in response to climate change and human uses of natural resources.

These studies included a broad range of disciplines ranging from glaciology to botany to entomology and included scientists and students from eight universities. The ACSP hosted 18 Peruvian students on 1-week long trips into Huascarán National Park so that they could gain hands-on experience working with the scientists. The ACSP was also able to provide funding for six Peruvian students to carry out research related to their university degrees. We also directly funded four US masters students to carry out their thesis work on this expedition. The ACSP also hosted a workshop at UNASAM in Huaraz to bring together investigators and local stakeholders. The funding for these opportunities was provided by grants to the ACSP from USAID and through charitable donations to the ACSP. All of ACSP lead scientists carry out the work on a strictly volunteer basis and do not receive any salary or profits for these projects.

Below is a report on the progress of each of the research projects carried out in Huascarán National Park in 2014. Most of these projects are long-term research and will hopefully continue in future years. We will make available any publications or reports on this research as they are completed. We sincerely thank Huascaran National Park and Jesus Gomez for making our work in this important region possible.

RESEARCH PROJECT REPORTS

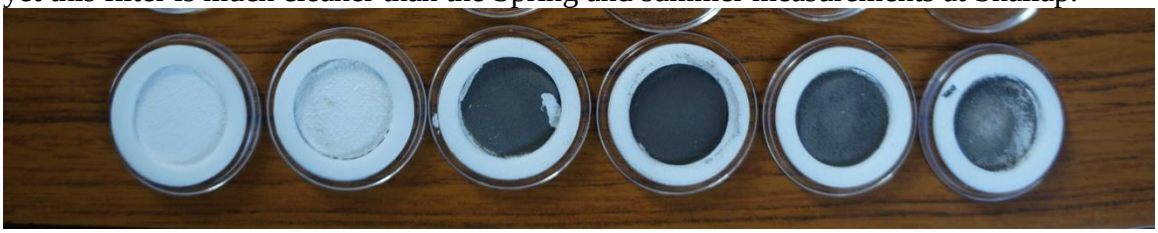
1. **Black Carbon in snow:** *Dr. Carl G. Schmitt, National Center for Atmospheric Research. schmitt.carlg@gmail.com: http://carlgschmitt.com/*

The ACSP Peru black carbon researchers are proud to say that our second publication on our measurements in the Cordillera Blanca is well on its way through peer review and should be published in the Spring of 2015 (http://www.the-cryosphere-discuss.net/8/5077/2014/tcd-8-5077-2014.html).

Results presented in this manuscript show that the mountains nearest to Huaraz have substantially higher concentrations of light absorbing particles, including black carbon, on their glaciers than more distant glaciers. This is likely due to the pollution produced by the city of Huaraz and nearby mining activity. Our research activities in 2014 were focused on confirming the trends that we observed in the 2011-2013 expeditions. In total, approximately 62 filter samples were collected from the Cordillera Blanca. Preliminary results from the measurements show that the trends observed over the first three years of sampling are holding in the 2014. The mountains nearest Huaraz have substantial contamination while mountains to the north have very little contamination.

<u>Year round measurements in the Cordillera Blanca:</u>
Hector Oropeza, who is conducting measurements on glacier mass balance for the University of Innsbruck, started snow sampling to facilitate our black carbon research in February 2013 on the Shallap glacier. Measurements from February and March 2013 (wet season) appeared to be very clean. After that (as the dry season began), the filters became heavily contaminated showing that dry season snow is substantially more highly impacted by light absorbing particles. Hector is continuing his measurements through 2015.

Given the differences observed during our previous research expeditions in the dry season, we have enlisted the help of Wilmer Esteban Sanchez Rodriguez to collect regular samples at Yannapaccha glacier. Wilmer is a student at Universidad Nacional Santiago Antunez de Mayolo (UNASAM) in Huaraz and is working as an intern for ACSP. Wilmer started taking measurements in September 2014 and his initial filters indicate that the Northern region is less impacted than the South, and the light absorbing particles appear to have stayed similar each month in contrast to what was observed last spring at Shallap. Wilmer reported that a lot of melting appeared to have occurred when he sampled in November which led to his dirtiest filter, yet this filter is much cleaner than the Spring and summer measurements at Shallap.

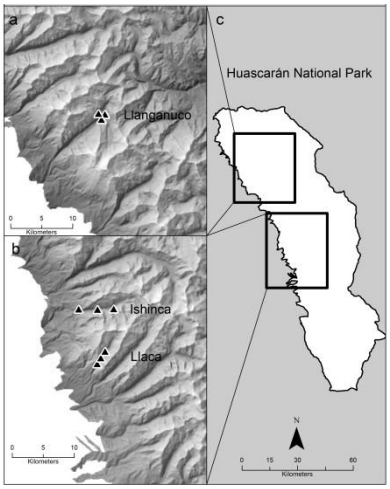


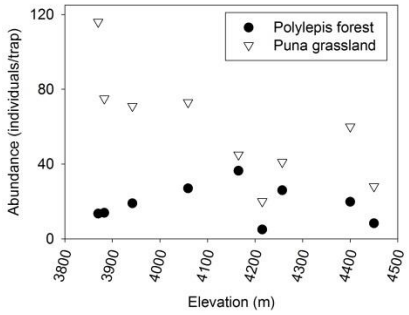
Shallap February March April May June July

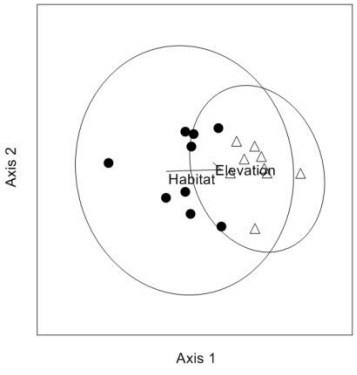
Yannapaccha September October November December

2. **Litter arthropod communities across high elevation gradients in *Polylepis* forest and Puna grassland in Huascaran National Park, Peru:** *Dr. Rebecca J. Cole, University of Hawaii at Manoa. cole.rebeccaj@gmail.com, www.rebeccajcole.com*

Land cover transformation and climate change are predicted to be major drivers of biodiversity loss in tropical ecosystems. Establishing baseline information on current distributions of biodiversity is critical for understanding the impacts of environmental change. This is the first study to examined patterns of litter arthropod abundance and diversity in two important habitat types, puna grassland and remnant Polylepis forests, across high-elevation gradients in the tropical Andes. Pitfall traps were placed in nine adjacent forest and grassland sites between 3800-4400 m in three major valleys on the western slope of the Cordillera Blanca in Huascarán National Park, Peru. We found that litter arthropod richness, diversity, and abundance were significantly greater in grasslands compared to forests; however, richness and diversity did not vary with increasing elevation. Litter arthropod abundance declined with increasing elevation in grassland but not forest suggesting that forests provide more stable habitats over elevation. Arthropod community composition between the habitats was quite distinct pointing up the key role of remnant Polylepis forests in conserving biodiversity in high-elevation ecosystems in the tropical Andes.



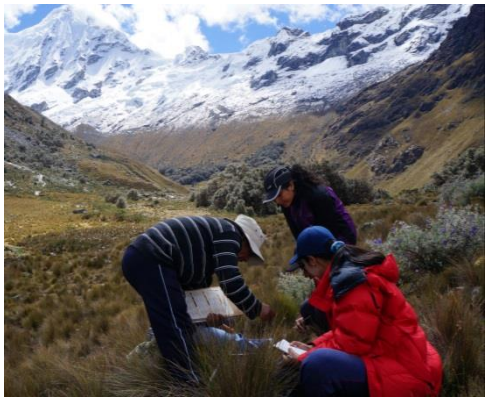




3. **Water Quality**: Dr. *Ruth Sofield: Western Washington University*

In July and August, 2014, water quality and benthic macroinvertebrate samples were collected from seven valleys (Quilcayhuanca, Paron, Llaca, Cojup, Ulta, Ishinca, and Llanganuco). Main stem rivers, tributaries, lakes, and glacier meltwater was collected from 118 locations in these valleys. In field measurements of the water included pH, temperature, alkalinity, and dissolved oxygen. Samples were transported back to Western Washington University (Bellingham, WA)

and are being analyzed for metal concentrations, selected anions, and dissolved organic carbon. Snow samples were also collected and will be analyzed for metals, selected anions and dissolved organic carbon. The snow samples corresponded to the same sites Dr. Carl Schmitt sampled.



The benthic macroinvertebrate samples were collected from 29 river reaches in the seven valleys. Water quality was collected at each of these 29 river reaches. A river reach was 100 m long. At each reach, six 0.3m x 0.3m Surber samples (mesh size = 500 microns) were used to collect benthic macroinvertebrates - which were composited in the field and preserved in alcohol. Specimens have been returned to Western Washington University for separation from plant matter, sorting, and taxonomic identification. These results will be used to determine the relationship between water quality and benthic community structure.

4. **Impacts of grazing on productivity and sustainability of high elevation grasslands and threatened *Polylepis* forests:** *Dr. Rebecca J. Cole, University of Hawaii at Manoa. cole.rebeccaj@gmail.com, www.rebeccajcole.com. Dr. Javier Ñaupari: Universidad Nacional Agraria La Molina y Dr. John All: Western Kentucky University*

High elevation Andean grasslands or '*Puna'* have been used by pastoralists for centuries and livestock grazing still comprises an essential part of local livelihoods throughout the Andes. In Huascaran National Park, high elevation valleys are used by local villagers to graze livestock. Grazing access is determined by both HNP rules and a variety of complex community-based systems. However, the consensus among local researchers and land managers is that a large proportion of land in HNP is in a state of moderate to severe degradation due to increased grazing pressure. In addition, these high elevation valleys harbor remnant patches of threatened native forests composed of the genus *Polylepis*. These *Polylepis* forests protect a large number of endemic and endangered plant and animal species but have been shown to be highly sensitive to grazing impacts resulting in stand degradation and size reduction. Beyond the immediate pressures on both of these critical ecosystems, rising temperatures and climate variability associated with climate change may affect the resilience of these ecosystems with direct consequences to local livelihoods.

Our work in 2014 assessed key information needs that directly inform local management of *Puna* grasslands and native *Polylepis* forest. Specifically we: (a) carried out an extensive assessment of grassland condition and grazing suitability across the western slope of the Cordillera Blanca; and (b) established a model set of grazing exclosure in degraded grassland to measure rates of recovery over time.

<u>Assessing current grassland condition across the western slope of the Cordillera Blanca</u>
The study included a description of the condition and characteristics of vegetation of the valleys of Paron, Quilcayhuanca, Ulta, LLanganuco, and Ishinca of the Huascaran National Park. Ecological sites were delimited for each valley using GIS information of slope, geology and vegetation.

Vegetation types assessed in these valleys were tall grass, short grass, bofedales (mountain wetlands), Polylepis forest, and shrublands. We used a "Rapid Assessment Survey", which allowed us getting a general description of the ecological condition of each rangeland site in every valley. Ecological condition was mainly focused for cattle grazing.

The information collected in each unit was plant dominant species, topographic position and landscape, soil erosion degree, water sources (permanent or temporary). Each valley will have a map of ecological site which will have a description of rangeland condition and trend, plant dominant species, and extension. Analysis of the results is in progress and will be presented in 2015.

Response of grassland to reduced grazing pressure across an altitudinal gradient

Understanding the rate of recovery of degraded pasture lands is critical for developing sustainable grazing practices. In coordination with HNP managers and local communities, we constructed a set of grazing exclosures in the Ulta Valley - an important water shed and grazing resource for the region. The project was developed by engaging the participation and input of the local Ulta Valley grazing association, a group of ~150 families that use this valley for their livestock. Starting in March 2014, the members of the grazing association were engaged in two meetings to discuss the need for this research and the best ways and locations to establish the project. The community voted to approve the project and the locations for each exclosure were selected with the approval of member of the grazing association.

In July-August, 12 member of the grazing association were selected through a lottery system to participate directly in the fence construction. Four 15x15m fences were built in a relatively low elevation pasture (3800m) and four were built in a higher elevation pasture at 4300m. Community member received training in fence building techniques and two community members have been selected (by the group) to be responsible for fence maintenance over the next year.

We carried out a suite of measurements of plant community structure, above-ground biomass, soil nutrients and soil structure in each of the eight exclosures and eight adjacent 15x15m unfenced plots. These measurements will be repeated annually and the results shared with grazing communities and land mangers through the region. The measurements were carried out with the participation of a group of eight local university students. The students received training in field methods and three students, one master's student (La Molina) and two undergraduates (UNASAM) are currently using this experimental as the basis for their thesis projects.

In addition to providing valuable educational opportunities for Peruvian students, this study is of great interest to the local grazing associations and national park administration and should provide key information on grassland resilience and management approaches. This project is continuing in 2015.

5. Economic Study in the Buffer Zone.
Rebecca Bria, ABD, Vanderbilt University

We have quantifyied current economic opportunities and possible alternative livelihoods in the buffer zone surrounding the Park through in-depth interviews with 112 local villagers on resource extraction and climate change in 14 different villages scattered throughout the Huascaran National Park buffer zone. Past researchers have found that the primary determinant of Andean pastoralist success in adaptation to climate variability was institutions that regulated use and that offered alternative economic

trajectories for local people and that the degree of integration into the economy was the greatest predictor of social stability. Peru conducts a decadal census and data from 1993 and 2005 are available (e.g. http://www.mundoandino.com/Peru/Peru-2005-Census). These data was supplemented with our semi-structured interviews conducted in villages adjoining the park in the buffer zone. Alternative and diversified livelihoods that optimize societal adaptation and reduce the long-term impacts of climate stresses are be the overall goal of this work.

PRESENTATIONS AND PUBLICATIONS ON PERU RESEARCH IN 2014

Workshops

Adaptación al Cambio Climático y Monitoreo de Servicios Ambientales en Comunidades Andinas / Climate Change Adaptation and Ecosystem Services Monitoring in Andean Mountain Communities. Huaraz, Peru. One day climate change adaptation workshop in Huaraz, Peru with >50 participants – primarily Peruvian university students, Huascaran National Park staff, and Peruvian government agency personnel, conservation organizations, local businesses, mountain guides, and students from ~twelve different universities

Monitoreo de los impacto de los contaminantes antropogénicos en la criosfera del los Andes/ Monitoring the impact of anthropogenic pollutants on the cryosphere of the northern Andes. Huaraz, Peru. One day work shop on glacier retreat and water impacts in Huaraz, Peru with nearly 60 participants – primarily local stakeholders, Peruvian university students, Huascaran National Park staff, and Peruvian government agency personnel

Adaptación al Cambio Climático en las Comunidades de la Cordillera Blanca. Caraz, Peru. One day climate change adaptation workshop in Caraz, Peru with thirty participants – mainly local stakeholders and Huascaran National Park staff

Qué Hacer Frente al Cambio Climático? Hualcayan, Peru. One day climate change adaptation workshop in Hualcayan, Peru with 50 participants – all local villagers – and presentations at a local schools.

Publications

Schmitt, C. G., All, J. D., Schwarz, J. P., Arnott, W. P., Cole, R. J., Lapham, E., and Celestian, A., 2014: Measurements of light absorbing particulates on the glaciers in the Cordillera Blanca, Peru, The Cryosphere Discuss., 8, 5077-5103, doi:10.5194/tcd-8-5077-2014.

Cole, R. J. and J. D. All. Litter Arthropod communities across high elevation gradients in Polylepis forest and Puna grassland in Huascaran National Park, Peru. Journal of Protected Areas. In review.

All, J. 2014. Remote Sensing Challenges in Mountainous Regions. *Photogrammetric Engineering and Remote Sensing*. 80(8):710-11. Includes interview.

Schmitt, C., J. All, R. Cole, A. Celestian, P. Arnott. 2014. Linking Remote Sensing and *In-Situ* Detection of Black Carbon on Tropical Glaciers. *Photogrammetric Engineering and Remote Sensing*. 80(5):385-390. Cover Article.

All, J. R. Cole, S. Arques, T. Woodall, J. King, J. Yan, and C. Schmitt. 2014. Climate Change Impacts on Fire Occurrence and Extent in Huascaran National Park, Peru. *Environmental Monitoring and Assessment*. In review.

Presentations

(Invited) Schmitt, C. G . Measurements of light absorbing particles on tropical South American glaciers, American Geophysical Union Fall Meeting, San Francisco, CA, Dec 16, 2014.

Schmitt, C. G . Panelist - panel discussion: "Black carbon in the Andes and Clean Energy", Universidad Nacional de San Antonio Abad Del Cusco, Peru, August 29, 2014.

Schmitt, C. G . Guest speaker at "Seminario: Black carbon in Andes and Clean Energy". Two presentations, "Black Carbon en los Andes" and "Tecnicas para evaluar BC y resueltos de la expedicion en el Asuangate", Universidad Nacional de San Antonio Abad Del Cusco, Peru, August 29, 2014.

Schmitt, C. G . Techniques and measurements of black carbon on glaciers in Peru, Invited presentation at the Universidad Nacional de San Antonio Abad del Cusco, Peru, August 22, 2014.

Cole, R.J. 2014. Restauración a través de diversos ecosistemas tropicales: Costa Rica, Hawái, Perú. Climate Change Adaptation and Ecosystem Services Monitoring in Andean Mountain Communities Workshop, Huaraz, Peru

MTNCLIM 2014, Midway, Utah. September 18, 2014. *Recent Environmental Changes and Effective Mountain Community Responses*. John All, Pat Arnott, Carl Schmitt, Rebecca Cole, Ruth Sofield, and Ellen Lapham.

Global Fair and Workshop on Long-Term Observing Systems of Mountain Social-Ecological Systems. Reno, Nevada. July 16-19, 2014. *Integrative High Alpine Research through Collaborative Partnerships*. John All, Pat Arnott, Carl Schmitt, Rebecca Cole, Ruth Sofield, and Ellen Lapham.