Ecohydrology and Water Resources of Monteverde, Costa Rica: Implications of a Changing Climate

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Ecohydrology and Water Resources of Monteverde, Costa Rica: Implications of a Changing Climate

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June, Mai, Merilie, and Ilona during the summer-2005 campaign

The Monteverde Institute
Alan Pounds, Monteverde, Costa Rica
Martha Scholl, USGS, Reston, VA
Achim Hager, Univ. of Gottingen
Simon Poulson, UNR, Isotope Lab
Ann Pufall, Aqueous Geochemistry Lab
Jon Caris, Spatial Analysis Lab
Monteverde lies on the Pacific side of the continental divide at 10°18′N, 84°48′W at an elevation of 1500 m.
Monteverde View on next slides
Looking NE from the road to Monteverde – June
Looking NE from the road to Monteverde – April
Why study Monteverde?

- **Cloud Forest**
  - Unusual environment in which forests are continually bathed in clouds and fog.

- **Biodiversity**
  - Home to many endemic species, including epiphytes, amphibians, and birds. Pounds et al. report anuran crashes, including Golden Toad and Harlequin Frog.

- **Water Resources and Ecotourism**
  - Monteverde Cloud Forest Preserve brings approx. 60,000 visitors per year (200,000 to the area).

- **Potential vulnerability**
  - Global climate change (Still et al., 1999) and lowland deforestation (Lawton et al., 2001) have the potential to reduce cloud formation.
Cloud Forest
Widespread amphibian extinctions from epidemic disease driven by global warming

J. Alan Pounds, Martin R. Bustamante, Luis A. Coloma, Jamie A. Consuegra, Michael P. L. Fogden, Pru N. Foster, Enrique La Marca, Karen L. Masters, Andrés Merino-Viteri, Robert Puschendorf, Santiago R. Ron, G. Arturo Sánchez-Azofeifa, Christopher J. Still, & Bruce E. Young

As the Earth warms, many species are likely to disappear, often because of changing disease dynamics. Here we show that a recent mass extinction associated with pathogen outbreaks is tied to global warming. Seventeen years ago, in the mountains of Costa Rica, the Monteverde harlequin frog (Atelopus sp.) vanished along with the golden toad (Bufo periglenes). An estimated 67% of the 110 or so species of Atelopus, which are endemic to the American tropics, have met the same fate, and a pathogenic chytrid fungus (Batrachochytrium dendrobatidis) is implicated. Analysing the timing of losses in relation to changes in sea surface and air temperatures, we conclude with ‘very high confidence’ (>99%, following the Intergovernmental Panel on Climate Change, IPCC) that large-scale warming is a key factor in the disappearances. We propose that temperatures at many highland localities are shifting towards the growth optimum of Batrachochytrium, thus encouraging outbreaks. With climate change promoting infectious disease and eroding biodiversity, the urgency of reducing greenhouse-gas concentrations is now undeniable.
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Water Supply

1 l/s will support about 400-500 people

AyA Sta. Elena y Cerro Plano (promedio mensual 2002)
- Ira Rosa (7 nacientes) 7.36 l/s
- Belmar (7 nacientes) 21.36 l/s

Leonel Quesada (10/98)*
- 4.18 l/s*

AyA Monteverde (2000)
- 4 nacientes
- 2.83 l/s época seca
Supply is out of phase with demand

Annual Average = 2700 mm

Amherst, MA = 1100 mm
Measurements made at the Monteverde Institute, Monteverde, Costa Rica.
Data are available at www.science.smith.edu/~aguswa
Watersheds of Interest

- QS200: 1.0 km²
- QM200: 3.6 km²
- QC200: 1.7 km²
- QSO100: 2.0 km²
- RG100: 19.4 km²
- RSL100: 14.1 km²

Rio Guadalal
Cerro Amigos
Continental Divide
Brillante Gap
Rio San Luis
Chemistry Summary

Adapted from Rhodes, et al., in press.
Watershed area = 1.7 km$^2$
100 l/s $\approx$ 5 mm/day

Q = 37 l/s

How important is the dry-season precipitation?
Stable Isotopes of Water

$^{2}\text{H}^{1}\text{H}^{16}\text{O}$

$^{1}\text{H}^{1}\text{H}^{18}\text{O}$

$\delta^{18}\text{O} = \frac{\left(\frac{^{18}\text{O}}{^{16}\text{O}}\right)_{\text{sample}} - \left(\frac{^{18}\text{O}}{^{16}\text{O}}\right)_{\text{VSMOW}}}{\left(\frac{^{18}\text{O}}{^{16}\text{O}}\right)_{\text{VSMOW}}} \cdot 1000$

- Delta values for terrestrial liquid waters are usually negative, and more negative values indicate lower concentrations of the heavier isotopes.
- Isotope concentrations are affected by evaporation and condensation. The shift is a function of temperature and relative humidity.
- When vapor condenses in a cloud, the heaviest isotopes condense and rain-out first. Thus, rainfall becomes progressively lighter as it continues.
- Transpiration does not cause a fractionation because roots do not discriminate among isotopes.
Stable Isotopes in Precipitation

June 2003 – April 2005

Adapted from Rhodes et al., 2006
Isotopic composition exhibits seasonal variation.

Adapted from Rhodes et al., 2006
Can we trace the precipitation signal to the streams?

$\delta^{18}O = -2.2‰$

$\delta^2H = -3‰$

Adapted from Guswa et al., in press
Spatial variation in $\delta^{18}O$ (‰)

Dry-Season Rain: $\delta^{18}O = -2.2‰$

Wet-Season Rain: $\delta^{18}O = -8.3‰$

Adapted from Guswa et al., in press
Monteverde – Continental Divide

Adapted from Guswa et al., in press
Monteverde: Regional Topography

Monteverde
Lac Arenal
Volcan Arenal
Rio Guacimal
Rio San Luis
Temporal Variation
Temporal Variation
Conclusions

- The water resources of Monteverde, Costa Rica depend on supply from streams and springs with very little storage.

- The greatest contributions of orographic precipitation to streamflow are in catchments near the Brillante Gap.

- In catchments affected by orographic precipitation, the temporal variation in stream isotopes generally follows the variation in precipitation but regresses to the annual average during the dry season.
Implications

- Streamflows for watersheds near the Brillante Gap depend on trade-wind delivered orographic water. Water resources in these catchments will be susceptible to changes in this precipitation input, which could be affected by global climate change.

- Streamflows in the dry season depend on water stored from the rainy season. Water resources will be affected by land-use changes that impact infiltration capacity.
Questions?

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www.science.smith.edu/~aguswa
References

