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# Ground level environmental protein concentrations in various ecuadorian environments: Potential uses of aerosolized protein for ecological research

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ABSTRACT

Large quantities of free protein in the environment and other bioaerosols are ubiquitous throughout terrestrial ground level environments and may be integrative indicators of ecosystem status. Samples of ground level bioaerosols were collected from various ecosystems throughout Ecuador, including pristine humid tropical forest (pristine), highly altered secondary humid tropical forest (highly altered), secondary transitional very humid forest (regrowth transitional), and suburban dry montane deforested (suburban deforested). The results explored the sensitivity of localized aerosol protein concentrations to spatial and temporal variations within ecosystems, and their value for assessing environmental change. Ecosystem specific variations in environmental protein concentrations were observed: pristine $0.32 \pm 0.09\,\mu g/m^3$, highly altered $0.07 \pm 0.05\,\mu g/m^3$, regrowth transitional $0.17 \pm 0.06\,\mu g/m^3$, and suburban deforested $0.09 \pm 0.04\,\mu g/m^3$. Additionally, comparisons of intra-environmental differences in seasonal/daily weather (dry season $0.08 \pm 0.03\,\mu g/m^3$ and wet season $0.10 \pm 0.04\,\mu g/m^3$), environmental fragmentation (buffered $0.19 \pm 0.06\,\mu g/m^3$ and edge $0.15 \pm 0.06\,\mu g/m^3$), and sampling height (ground level $0.32 \pm 0.09\,\mu g/m^3$ and 10 m $0.24 \pm 0.04\,\mu g/m^3$) demonstrated the sensitivity of protein concentrations to environmental conditions. Local protein concentrations in altered environments correlated well with satellite-based spectral indices describing vegetation productivity: normalized difference vegetation index (NDVI) ($r^2 = 0.801$), net primary production (NPP) ($r^2 = 0.827$), leaf area index (LAI) ($r^2 = 0.410$). Moreover, protein concentrations distinguished the pristine site, which was not differentiated in spectral indices, potentially due to spectral saturation typical of highly vegetated environments. Bioaerosol concentrations represent an inexpensive method to increase understanding of environmental changes, especially in densely vegetated ecosystems with high canopies or in areas needing high spatial and temporal resolution. Further research to expand understanding of the applicability of bioaerosol concentrations for environmental monitoring is supported by this pilot study.


## 1. Introduction

The ability to remotely and non-invasively measure indicators of environmental and biological change have been a driving force in ecological research over the past decade from satellite imagery of deforestation to non-invasive DNA testing of various animal populations using shed materials (Caruana, 2011; Garshellis, 2006; Jha and Bawa, 2006; Jiang et al., 2014; Mucci and Randi, 2007; Vina et al., 2004). A promising remotely-collected integrative ecosystem indicator is provided by aerosolized proteins, or bioaerosols (Castillo et al., 2012; Huffman et al., 2012; Pauliquevis et al., 2012; Santarpia et al., 2013). It has been recognized that ambient

*Abbreviations:* NPP, net primary production; NDVI, normalized difference vegetation index; LAI, leaf area index; TSP, total suspended particulates.

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air is composed of a “protein soup” containing bacteria, viruses, spores, pollen, and a slew of biological debris from humans, animals, insects, and plants all ranging in size from a few nanometers to roughly 100 microns. To date most research examining bioaerosols has concentrated on either indoor environments or atmospheric studies (Kang et al., 2012; Schneider et al., 2011; Staton et al., 2013). These studies have focused on determining local air quality, possible pathogenic transmission of aerobacteria and viruses, bioaerosol output of particular locations such as a trash dump, or the effects of large scale fires (Alvarez et al., 1995; Costa et al., 2012; Menetrez et al., 2009; Rogers et al., 1991).

Atmospheric protein studies have confirmed the existence of large quantities of aerosolized material of biological origins with as much as 56 Tg/year (>1 μm in size); however, there have been few to no studies investigating localized ground concentrations of bioaerosols or how these concentrations vary among ecosystems (Baars et al., 2012; Despres et al., 2012; Jaenicke, 2005; Rizzo et al., 2010, 2013). Besides harboring information detailing their origin through DNA and protein profiling, the sheer amount of bioaerosol material in the air could potentially provide an index of biological activity in the area. It is already known that large protein fragments shed as sloughed skin, feathers, and shells can be used as sources of DNA, amino acids, and protein profiles to investigate a single population or species (Boulanger et al., 2008; Hansen et al., 2008; Hogan et al., 2008; Kelly et al., 2014; Valle et al., 2009; Waits and Paetkau, 2005). However, broad-scale use of bioaerosols to characterize geographic areas and detect environmental change has been largely unexplored.

The aim of this study was to collect and survey total suspended particulates (TSP) samples from diverse environments throughout Ecuador representing ranges of ecosystem productivity and human alteration, in order to evaluate the amount of bioaerosol material, the relationship of bioaerosol concentration to the environment of origin, as well as specific intra-environmental comparisons. Intra-environmental comparisons described bioaerosol response to variations in seasonal and daily weather, forest fragmentation, and sampling height. Bioaerosol concentrations were then compared to several satellite-based spectral indices to determine their agreement with other indicators of ecosystem productivity.

## 2. Material and methods

### 2.1. Study areas

Samples were collected in a pristine humid tropical forest (pristine), highly altered secondary humid tropical forest (highly altered), secondary transitional very humid forest (regrowth transitional), and a suburban dry montane forest that has been mostly deforested (suburban deforested) (Table 1 and Fig. 1). Secondary forests are differentiated by the relative alteration due to human activities including deforestation activity, agriculture, and human habitation. All samples were collected during 2009, which happened to be a drought year when annual precipitation at Quito was 40% of the 100-year average. Variations in the number of samples collected per location and sampling condition reflect the availability of the testing sites and equipment reliability.

The pristine site was in a humid tropical rainforest located in the Tiputini Biodiversity Station sponsored by the Universidad San Francisco de Quito at 229 m elevation. The reserve is located on the Tiputini River, a tributary of the Amazon River, and is directly across the river from Yasuní National Park. The site is in the far eastern portion of Ecuador with minimal, mostly indigenous human population, and is currently mostly insulated from petroleum extraction and logging. Sampling occurred in mid-October 2009 and was conducted at two heights: 0.76 m, considered ground level, and 10 m, the greatest height that could be safely sampled. The typical canopy height at Tiputini was 45 m. Wildlife activity was observed near the sample site, including squirrel (*Saimiri sciureus*) and woolly (*Lagothrix poeppigii*) monkeys within 5–15 m while spider monkeys (*Ateles*) and golden mantled tamarins (*Saguinus tripartitus*) were within 25–50 m. The animals did not appear to be disturbed by the sound of sampling equipment suggesting minimal noise pollution and minimal sample bias toward lower values due to vertebrates or insects avoiding the area.

The regrowth transitional site is near Tena, located on the eastern slope of the Andes Mountains facing the Amazon Basin at 445 m. Samples were collected on the grounds of the Andes and Amazon Field School located on the Napo River. This area lies between basin rainforest and cloud forests at higher elevations. At the time of collection the area was not agriculturally active, and

**Table 1**
Ecuadorian sampled location names and site descriptions.

| Location name | Description | Latitude/longitude | Elevation (m) | Annual precipitation (mm) | Samples |
|---|---|---|---|---|---|
| Secondary transitional very humid forest-buffered (Tena) | Eastern slope Andes, buffered by a kilometer of forest | S 01°02′36.7″ W 077°43′05.0″ | 445 | 4500–5000 | 5 |
| Secondary transitional very humid forest-edge (Tena) | Eastern slope Andes, constrained physically within 25 m | S 01°02′21.8″ W 077°43′09.0″ | 445 | 4500–5000 | 6 |
| Highly altered secondary humid tropical forest (Ipatoá) | Western slope Andes, has significant agricultural activity and within 25 m of a road | N 00°07′22.0″ W 079°16′16.9″ | 135 | 2000–2500 | 3 |
| Pristine humid tropical forest (Tiputini, 0.76 m) | Amazon basin in the Tiputini River watershed sampling at ground level | S 00°38′12.9″ W 076°08′59.2″ | 229 | 2500–3000 | 4 |
| Pristine humid tropical forest (Tiputini, 10 m) | Amazon basin in the Tiputini River watershed sampled at 10 m | S 00°38′12.6″ W 076°08′59.1″ | 229 | 2500–3000 | 7 |
| Suburban dry montane forest (Tumbaco) | Andean suburb of Quito in a residential area | S 00°13′51.0″ W 078°23′42.8″ | 2,432 | 1500–2000 | 15 |