Deforestation and Drought: Environmental Impacts on Rapa Nui (Easter Island)

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Prospectus Proposal Approval

30 January, 2008

Deforestation and Drought: A Complex Interaction Between Environmental Changes and Transformation of Human Culture Systems on Rapa Nui (Easter Island)

Understanding a changing ecosystem is complex and dynamic. As dynamic as water that shapes its environment is to the complexity of rainfall changed by climate. These connections are one of the important keys to understanding diversity in the natural world. By establishing an isolated lake system's response to climatic change, we can begin to understand adaptive responses within that ecology, as well as discovering the behaviors of humans that subsisted, modified and adapted within that ecosystem. It is Rapa Nui, a rare, unique mystery, with a poorly understood climate history that is the subject of this multi-proxy ecological discovery of an isolated island and the lake Rano Kao, its inhabitants and the phenomena that is writing its history.

Research Objectives

The focus of this research is to realize the long-term ecological dynamic of the crater-lake Rano Kao as part of the ecosystem Rapa Nui (Easter Island)*(Appendix1; Figure 1)*, a seemingly barren grassland devoid of trees. The crater lake Rano Kao, sits on the southwest corner of the tiny island where it has been mostly undisturbed for thousands of years. It was also here, where the last native tree was seen alive. Its basin has been accumulating airborne pollen, charcoal and volcanic ash as well as slowly collecting decomposing plants that change and adapt with lake water level rise and fall. Sensitive and responsive to moisture changes, the lake once appeared to be open and full of algae, now the surface carries a floating mat of *totora* (*schoenoplectus californicus*) and *polygonum acuminatum*, that formed in the recent past during a long period of drought. By close vertical column sampling using micro and macrofossil identification, new radiocarbon dates have been established and oxygen isotope analysis has disclosed temporal changes in water level fluctuations unfolding a new understanding of the ecological transformations of Rano Kao that were dependent on moisture. (*Preliminary $0^{18}/0^{16}$ analysis see Appendix1; Figure 2*).

The expected outcomes of this research include:

1. A long term climate profile ranging from 1000BP to 15,000BP including Interglacial to Holocene time periods that includes patterns and cycles of drought and wet periods that occurred before human arrival
2. Ecological changes in the lake including plant, animal and mineral
3. Identify environmental indicators of changing temperature and moisture
4. Identifying the morphological changes in scarps seeds over time and determine if a new species was introduced by prehistoric human immigrants to the island
5. A lake bottom profile documenting differences in water depths that may lead to identification of speculated tutor cultivation in the lake
6. Evidence for the first human occupation of the island based upon changes in pollen and carbon particle frequencies
7. Confirmation of volcanic/burn events suggested by the magnetic scans of sediment cores

Systematic methods of obtaining the information for this research *(Appendix1; Figure 3)*, including aquatic plant cellulose isotope analysis, is unique to the science of the island and has never been applied before. These results use $0^{18}/0^{16}$ ratios to detail changes in lake levels, and infer moisture and temperature cycles. These cycles are also seen through the investigation of pollen. Pollen counting and identification visualizes the plant ecology of the lake as it changed over time. Thus far the fossil pollen found in the lake cores is more receptive to collecting the immediate species within the crater, but also found are the windborne palm pollen that came from ancient forests on the island. To compliment the pollen work, raw sediment macrofossil analysis (non-pollen palynomorphs) will disclose information about minerals and animals like bacteria and algae that help form peat, that are otherwise lost in the process of pollen slide procedures. These plant allies are also good indicators of environmental change being sensitive to temperature and moisture fluctuations.

Scientific Background and Research Expectations

What is known about Rapa Nui is mostly related to the Late Stages of human occupation. Missing is the details to the natural world and what the island was like before humans arrived. In order to understand the significance of this research project, then, we will place it in context with the previous research conducted on the Rapa Nui environment.

Previous to the Norwegian Expedition of 1955, which discovered an ancient palm pollen in the soils at Rano Raraku, the island was thought to be treeless. Over time, through sediment studies and pollen analysis, researchers discovered that the island was in fact sub-tropical and covered by a palm species similar to the Chilean wine palm capable of growing up to 2 meters in diameter. John Flenley (1984, 1991) published works on his sediment coring in the three crater lakes Rano Kao, Rano Aroi and Rano Raraku and proposed that Easter Island was formerly forested with trees of varying species and size including *Sophora toromiro* and *Triumfetta semitriloba*. In following Flenley's coring from 1984 and 1991, I am the second person to successfully core in this lake. This research project, then, continues to build upon John Flenley's previous work and to expand upon the current ecological knowledge. In the initial core KAO3A, which is older than any other taken yet in Rano Kao, we have already discovered three palm types and a new species of tree/shrub not yet known to the island. Core KAO3A, taken 400 meters from the edge and very near to center of lake, represents plants that were growing on the surface of the lake and how they changed with rainfall patterns. This core is, therefore, a good indicator to how the lake ecology responded to climate shifts.

The finding of an extinct, Achatenelid (land snail) in the soils by Kirch and Christensen (1991) is an important indirect indicator of a forest presence that depended on woody growth for their survival. By analyzing raw sediment samples from the core, certain macrofossils such as snails, chitin and beetles, can be utilized in understanding plant allies that are also sensitive to moisture changes and indicate environmental change. Counting and identifying the presence of these allies, both as macrofossils and as non-pollen palynomorphs (Bas van Geel, 2001) found in microfossil pollen slides, we will be able to recreate a more sensitive picture of a changing system.

Flenley quotes from Birks and Birks (1980) that the use of *intuitive methods* of vegetation reconstruction with a well-defined narrow ecological tolerance rather than counting modern pollen rain alone, can be useful in reconstructing former climates. Therefore Flenley used indicator species with ecological preferences to compare climate inclinations such as cool – warm, moist – dry, mesic – stressed. Once the pollen is identified and counts are known, ecological indicators that Flenley pointed out will be useful. More important in this study is the adaptive movement of the plants dependent on the lake changes. For instance, it has been discovered in the core thus far, that *scirpus*, although present back to 15,000BP, is not an aggressive plant. When conditions become dry and water low, the plant retreats to the margins and *polygonum* takes over. It is polygonum that formed the floating surface mat, and its presence informs us of dry and boggy lake conditions.

Radiocarbon dates acquired during previous coring attempts have had problems with bulk dating. Pollen is scarce on the island and this makes AMS dating with pollen also problematic. Therefore, the first and most important step in this research was to determine a dependable chronological profile. By being very specific and picking *scirpus* seeds from core samples, we have been able to create a solid radiocarbon-dated profile that sets the foundation for all of the studies that are proposed. The chart below *(Appendix1; Figure 4)* shows the profile established from these seeds in KAO3A.

A new method was needed to discover climate change affects on the island and how that affected rainfall patterns. Aquatic plant cellulose from the core samples are being used to note the changing oxygen isotopes as well as carbon and nitrogen levels that tell us how the lake was responding to climate change over the last 15,000 years. In the preliminary analysis, there are noticeable cycles of drought and wet periods. When completed this long-term climate profile can be used to determine human presence as noted through charcoal evidence, changing sedimentation rates, and introduced species found in the core. We can look at the changing lake response and determine if humans had an impact on their local environment. Irving Friedman (1997) observed on Marajo Island, off the coast of Brazil, that when half of the island's forest was cut that rainfall patterns also change appreciably. The cut side only received one-third of its previous rainfall while the forested side retained two-thirds of its precipitation through evapotranspiration. The ecology changes drastically through a trickle effect. Perhaps we will discover similar effects on Rapa Nui, but first we must determine if climate change affected the forests of Rapa Nui before we can claim that humans had an impact on their environment.

Work Plan--what my gracious collaborators and I have done thus far:

March 2005 – core at Rano Kao, obtained 20 meter, four borings. KAO05-3A primary.

April 2005 - Limnological Research Center, Minneapolis. Archive, SI, core sampling.

July 2005 – Candace Gossen and Chris Stevenson publish paper entitled "*Prehistoric Solar Innovation and Water Management on Rapa Nui*" that was published by the International Solar Energy Society World Congress.

July 2005- Massey Univ., Palmerston North, NZ, Prof. John Flenley coring and pollen processing 90 soil samples.

February 2006 – Lawrence Livermore National Laboratories (LLNL) 20 samples RC samples.

April 2006 – 45 samples-Brent Wolfe, at Wilfrid Laurier Univ, Waterloo, Ontario, O18 analysis.

Summer 3006 – test samples by Bernd Strewiski for diatoms and ostracods (negative results)

March 2007 – 4 samples to LLNL for dating the mat above the KAO3A lake sediment core

September 2007 – Article published in the Rapa Nui Journal v. 21, Number 2, October 2007, p. 105. *The Mystery Lies in the Scirpus* (attached to this application).

September – December 2007 – University of Minnesota (UMN), Ecology Dept. working with Prof. Ed Cushing on pollen and macrofossil analysis.

November 2007 – Chris Stevenson and Candace Gossen awarded a small grant from Aviva/Earthwatch to continue research on climate change on Rapa Nui. These funds will be used for Candace to core the mat on the island February 2008, RC dating, and isotope analysis.

December 2007 – 6 samples sent up to Brent Wolfe for isotope analysis of mat samples

Current and Future work funded by this grant proposal:

April – June 2008 – Continuing work at UMN in Ecology Dept. Lab.

Summer 2008 and beyond – The mat cores retrieved from the island in February will be sampled and processed for pollen, macrofossils and isotopes. This is a continuation of the lake sediment core KAO3A that ranges from 1000BP to 15,000BP. The mat cores will contain data ranging from modern to 1000BP. Writing of the dissertation will continue with an expected completion date of December 2008.

Significance of the Proposed Research

This work will change what is known about ancient climates and how the Rapa Nui adapted to new environmental conditions of the recent past. I expect to answer questions about first human occupation of the island, human-introduced species of plants, climate change both on a local and global scale, and possibly the human cultivation of plants at Rano Kao. The tools and methods learned here would be useful in many other contexts where a reconstruction of forest ecology can be obtained from soil and lake sediments. The outcomes can be used for comparative studies in the Pacific region and beyond. This study has great potential to help humans understand the interconnections of natural systems and how humans fit into them, especially when considering climate change future demands for water.

Appendix 1

Fig. 1 Map of Rapa Nui in relation to other islands and South America.

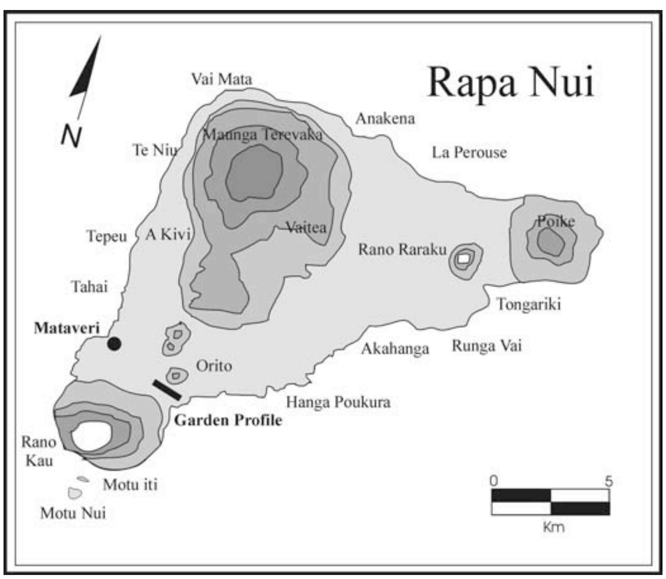

Figure 1a. The island, Rano Kao bottom left.

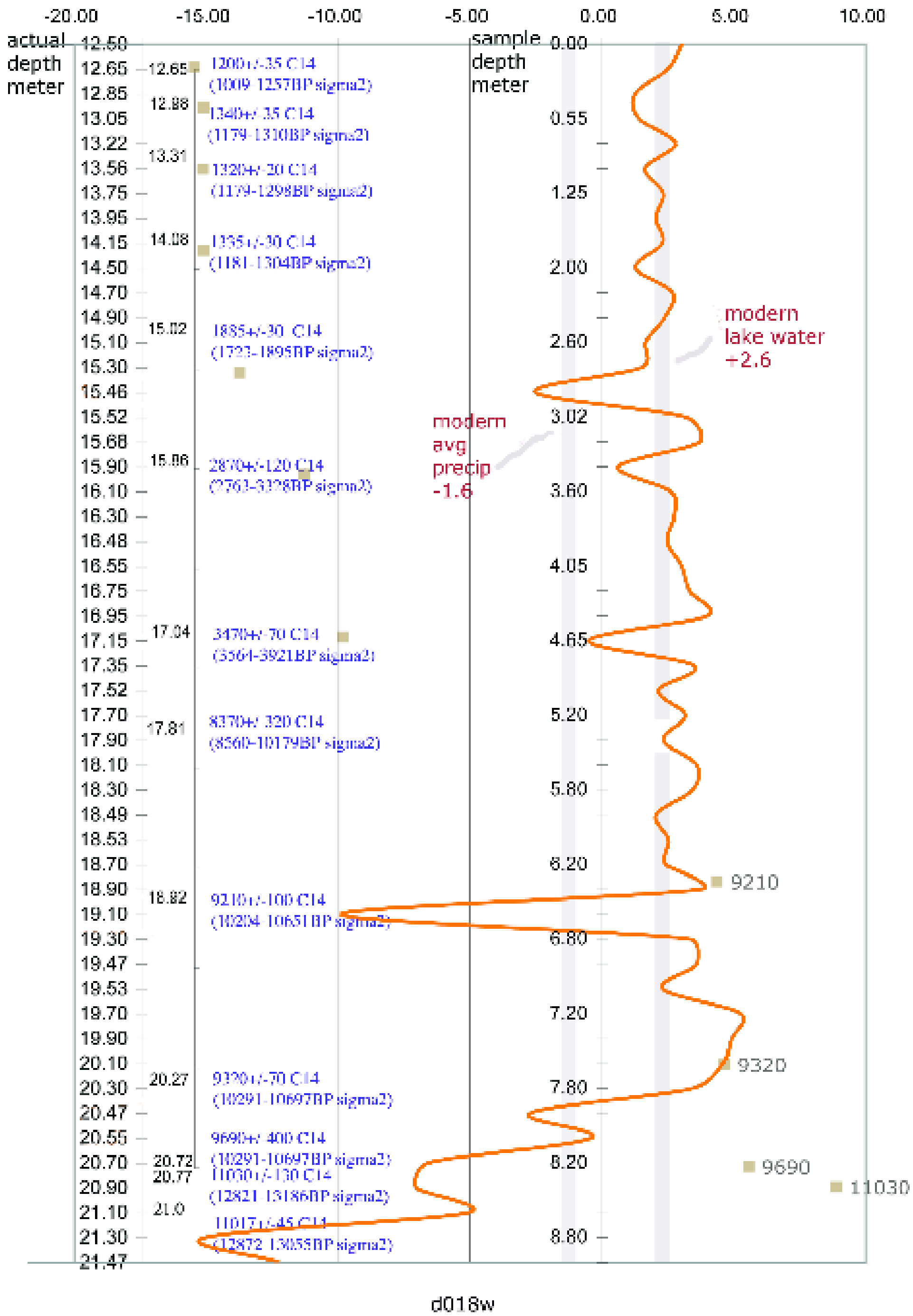

Figure 2. Preliminary Cellulose Isotope Analysis from KAO3A core along w/ radiocarbon dates

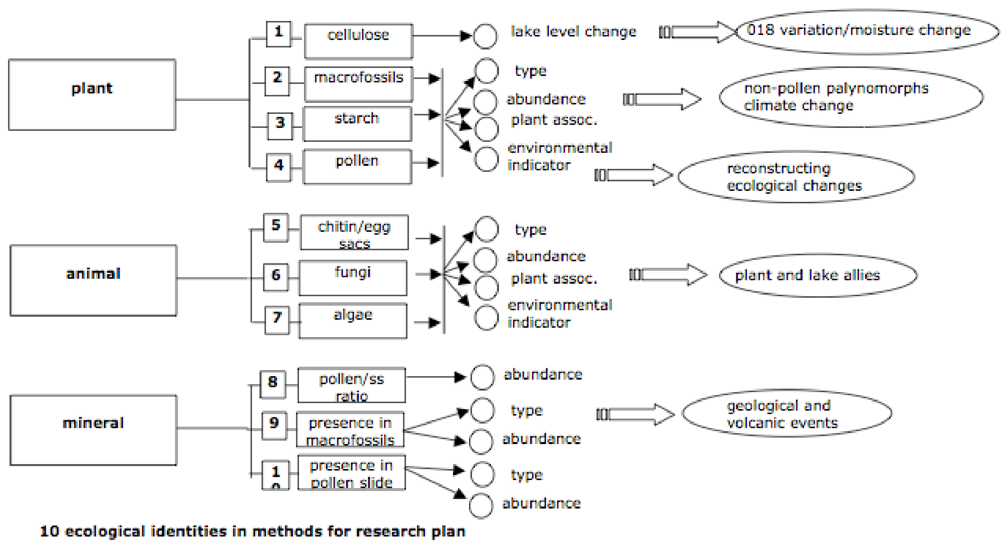

Figure 3. Methods Diagram for Work Plan of this research

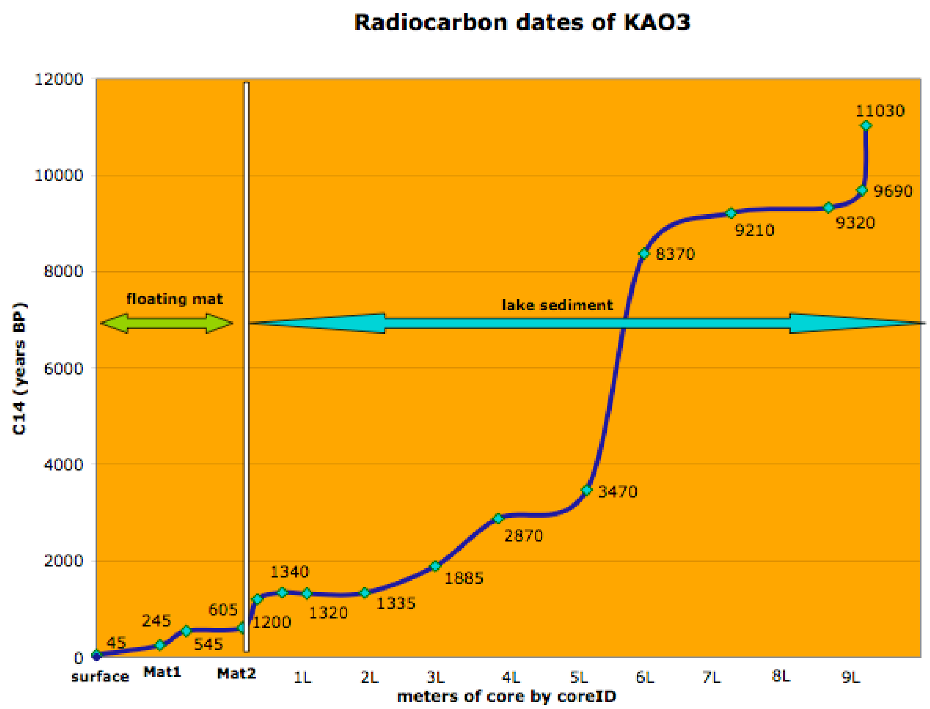

Figure 4. Radiocarbon dates of scirpus seeds in core KAO3A

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Candace Gossen - Budget and Statement of Need

I have been very fortunate throughout most of this research in that I have been able to teach as an adjunct instructor with Portland State University and as a community education teacher for Portland Community College while raising my son as a single mom. This past year we made a shift, he graduated high school and started college himself. I am most graciously happy to see the end of this phase of my research so that I may move forward and also now help him financially with college.

In the work plan portion of the proposal I listed the previous work that has been completed and mostly funded by myself, with the occasional help of funds from the Easter Island Foundation for radiocarbon dates; free sample dating from LLNL; gratis work from the Isotope Lab at Wilfrid Laurier; pollen processing at Massey Univ., NZ; travel reimbursement by PSU for original coring in 2005; full lab courtesy of LRC and the Ecology Dept. at UMN, and countless energy over the past 5 years from John Flenley, Chris Stevenson, Tom Guilderson, Brent Wolfe and Ed Cushing.

All tuition and fees have been paid by me and will be expected to do so until I am finished with the degree. All expenses to travel to these locations, live there or work there have been on my expense, as well as buying a microscope for my work and other tools and equipment. At the end of March I will no longer have a teaching job with PSU and therefore have no foreseen income during my stay at UMN spring 2008, summer and beyond while completing the assimilation and writing of my dissertation.

At the end of March I will no longer be employed with Portland State University. My previous pay per class at 1-2 classes per term is FTE of 0.27 at $740 per credit hour or $2960 per quarter per 4-credit class.

Rapa Nui Field Work (March 2005)

1) airfare	$2,000 Candace (1)
2) lodging	800 Rob Dunbar (Stanford) (2)
3) coring equip, labor, freight for cores, etc.	$5,000 PSU travel reimbursement (3)

LRC core processing and sampling (April 2005)

1) magnetic susceptibility and core prep	$ 578 PSU faculty enhancement grant (3)
2) pollen sampling	$1,189 PSU faculty enhancement grant (3)
3) RC samples	$ 300
4) new mat samples Feb 2008	$ 600 (**)

New Zealand (July 2005)

1) 3 weeks – room & board, airfare	$3,105 PSU faculty enhancement grant (3)
2) lab analysis pollen	850 PSU faculty enhancement grant (3)

LLNL (February 2006)

1) 20 samples	$6000 (EIF paid $3600) remaining gratis

2) airfare to Livermore	$ 225(1)
3) lodging & food (3 nights)	$ 300 (1)
LLNL (new mat samples)	
1) 4 samples @ $600 each	$2400 (**)
Wilfrid Laurier, Isotope Lab (2007)	
1) isotope (cellulose) 45 samples	$ gratis (lake sediment samples complete)
2) mat samples (20 @ $120)	$2400 (**)
Rapa Nui, coring Feb 2008	
1) airfare	$2000 (**)
2) lodging (at farm) & food	1000 (**)
3) coring equipment rental	300 (**)
4) incidentals (shipping, etc.)	500 (**)
Univ. of Minnesota	
1) expenses for 3 months Sept. – Dec2007 pollen, macrofossils, core lab work	$7000 (1)
2) spring Apr – June 2008 housing	$1275 (1)covered by rent of my house (pdx)
3) food and expenses	?????(1) to be paid by Candace 2nd mortgage
complete lab analysis	priceless (time)
write dissertation	priceless (time)
Summer and beyond	
writing of dissertation	
additional lab analysis as needed	
Living Expenses (portland)	$15,000 (estimate) ~$1,200 per month x 12 months

***amounts in blue denote unpaid balances or costs covered by Earthwatch/Aviva Grant awarded Dec 2007 to Chris Stevenson and Candace Gossen for cllmate change research on Rapa Nui.*
All items in orange are those that will be conducted thru the grant awarded for this proposal.

Budget Justification Notes:

1. Candace Gossen, the researcher of this project has supplied some of the costs of this project including airfare to Easter Island and New Zealand, and the purchase of a microscope.
2. Rob Dunbar and his Stanford group offered shared lodging with one of his female team members during the course of our field work in March 2005.
3. A PSU Faculty enhancement grant was applied for in January of 2005 in joint collaboration with Dr. Aslam Khalil and Candace Gossen for a total of $10,000.
4. The Easter Island Foundation granted $3600 dedicated to Radiocarbon dating of the Easter Island core. Normal rates for pollen RC dating is $600 USD, but a reduced student fee is being offered to Candace to process the RC samples at the LLNL AMS lab for $300 per sample.
5. Isotope Analysis, Brent Wolfe, Wilfrid Laurier Isotope Lab, $120 per sample