Introduction

Rapa Nui *Te topaanga o te ei o hina kauhara**: a search for moisture,*** is a multi-faceted dissertation research project that asks important questions about water, particularly indices of rain and its impact on Rapa Nui prehistoric societal development. Through an interdisciplinary approach, many environmental details that characterize past ecological conditions will be used to develop a larger picture that reveals the conditions of a place and a people both adaptive and responsive to changing moisture. All societies, no matter how isolated require water to exist and thrive, and what is missing from the knowledge of Rapa Nui is how climate change, especially droughts and environmental degradation affected the social evolution of its people. This project seeks to document forest decline, and the ecological impact of prehistoric settlement on Rapa Nui along with a detailed record of climate change focused over the last 2000 years.

Every ecosystem has a carrying capacity and it is this environmental potential that has been speculated upon when considering the cultural collapse of Rapa Nui. Inferences are sometimes necessary but often missing critical keys to understanding. In particular when considering human impact generally terms of soil erosion, deforestation and species extinction are often focused upon. A typical scenario would be: populations grow, interact, intensify agrarian food production, deforest the region, deplete the soils and then ultimately abandon the area. But what about the adaptive and responsive behavior of human intelligence? By unlocking details about the moisture climate of Rapa Nui, particularly what happened with rainfall, evapotranspiration and soil moisture we can then begin to understand human action and response. The island is unique in that there is little known about its climate history. Located outside of the historical shipping passageways, SST hardly existed before 1981. ENSO studies also have found that Rapa Nui may not be affected by the southern oscillation and may actually hold keys to understanding larger climate systems on planet Earth (Genz & Hunt, 2003).

The common thinking of what has been known about Rapa Nui is that in the 16th century the culture had become a highly organized Polynesian chiefdom, investing substantial labor into the creation of massive stone temples (*ahu*) and statues (*moai*). This socially complex society also supported the farming of root crops such as taro and sweet potato that became intensive and was conducted under stressful conditions brought on by erratic rainfall patterns. Abruptly, in the late 17th century, there was a collapse of this great megalithic civilization that led to fragmented hierarchy, warfare and movement to cave dwellings. With very little being known about Rapa Nui previous to the 16th century most archaeologists have used discovery of human presence to determine first occupation, while paleozoologists look to extinctions of species as a proxy of human contact, where palynologists look into soil for changes in rapid sedimentation rates, charcoal accumulation and changes in pollen. Alone each cannot tell the discrete inference of human occupation, but a multiple proxy inquiry such as this research project proposal, can give a broader, fuller understanding and "non-human causes of environmental change that could help refine estimates of the timing of human occupation." (Nunn, 2001).

So then what caused the changes on the island? Three explanatory scenarios from varying disciplines have been proposed. A few scholars have proposed that climate change was the primary variable responsible for change? (Hunter-Anderson, 1998; McCall, 1993; Orliac. and Orliac, 1998; and Nunn, 2000). Others propose that deforestation changed the landscape so drastically as to cause droughts that drastically altered productive capacity? (Butler and Flenley, 2001; Bahn and Flenley, 1992). Recently, one scholar has proposed that other cultures arrived on the island and interfered with the political process (Dumont, et al., 1998).

In 1999, archaeologist Chris Stevenson (Stevenson, Wozniak, Haoa, 1999) discovered the use of lithic mulch, volcanic rock, covering the pre-existing garden surfaces. Clearly the lithic mulch was being used as a method to either conserve or create moisture to continue the growth of food. Terrestrial records that document vegetation and environmental changes viewed against long-term moisture records revealed from isotopic analysis of coral and ostracoda is an excellent research strategy for establishing the affects of human impacts on moisture limited landscapes. This study is the quintessential research to tying together archaeological, environmental and geographic information by asking specifically of Rapa Nui; did the island's moisture climate change? And if so what caused this change?

Disseminated broadly to enhance scientific and technological understanding

Potential impacts of this study are enormous and address important topics in world prehistory. It would provide archaeologists with a geographic sampling for palynological analysis that is currently lacking. It would also reconstruct aspects of the climate that are not known that would help us understand the relationships between environmental change, resource use and human decision making. This research will also guide further human impact studies, micro-macro climate studies, human innovation, changes in introduced and endemic species, ecosystems response to moisture change, ENSO/global warming studies and human migration. All of these topics have a broad audience including archaeologists, anthropologists, ecologists, geographers, geologists, oceanographers, climate change researchers, and mostly the people of Oceania.

Interdisciplinary research helps broaden the scientific view. Applying this acquired knowledge to larger scale questions such as climate change, global history, and the interconnectedness of human populations require multi-disciplined fieldwork and testing. This comparative analytical project demands the scientific method to unlock a broader view and will be the basis for further post-dissertation grants. In especially rare cases like Rapa Nui, can one isolate conditions to test for these interactions.

Background information

Water and sediments from the crater lakes

Today the landscape of Rapa Nui is largely treeless dominated by bunch grasses growing on the slopes of volcanic cones. There are three main crater lakes (Figure 1), one at the southwestern corner of the island called Rano Kau that erupted 2.5 million years ago. Rano Raraku otherwise known as the moai quarry is near the dry volcano of Poike, the oldest formed at 3 million years ago. Poike's small summit crater, Puakatike, today is dry but contains a eucalyptus grove planted in the mid 20th century. A third crater lake, a reed swamp at Rano Aroi, is on the slopes of Terevaka that formed 300,000 years ago. Of all the violent eruptions that formed Rapa Nui, the most spectacular was the formation of the Rano Kau crater (Eduardo Ruiz-Tagle).

There is one permanent surface stream that originates from Rano Aroi and many brackish springs along the coastline (Heyerdahl, 1961). There are dry streambeds that give the impression that rainfall is sporadic and slight. All in all surface water is scarce on the island today.

All three crater lakes contain freshwater with deposits that are highly organic. Each has varying depths, sedimentation rates, accumulated pollen, carbon, diatoms, ostracods and algae. Human occupancy and use was common of all throughout history.

Rano Kau crater lake (Figure 6) is the deepest with unknown sediment depth. There is a three-meter continuous totora (*Scirpus californicus*) and polygonum (*acuminatum comp.*) reed matting that contains an anoxic 8 meters of water beneath (Figure 3a & 3b). It was the last lake on the island to contain forests of toromiro (*Sophora*) (Figure 4) and because of its sheer size and volume make this lake the most stable and most useful for climate details.

Rano Aroi, a much shallower reed swamp located on the slopes of Mount Terevaka, is the youngest lake and most varied. It has been very useful in the past studies by John Flenley (1984 and 1991) in his determination of isolating sensitive plant species to climate change. Its sedimentation rate is slow therefore not requiring much depth to cover his findings of 35,000 years of environmental change. In the 1920s this swamp was modified with a dam and therefore greatly disturbed.

Rano Raraku is the most eroded landform (Figure 2) and is the home of the *moai* quarry (Figure 3a & 3b). It has some growth of totora (*Scirpus californicus*) on its surface. The lake bottom is flat as determined by Mann et.al. in 1997 by running transects with an echo sounder determining a depth of 6-7 meters at its center. In 1998 Dumont's macrofossil studies at Rano Raraku determined the introduction of ostracod (*Sarscypridopsis* cf. *elisabethae*), as well as diatoms (*Achnanthes* cf. *abundans*) from subantarctic origin and (*Nitzschia* cf. *vidovichii*) of South America. This lake has classic irrigation channels and has a weathered cliff face that was once connected to the Pacific Ocean.

Coral

In order to create a broad overlying picture of what was happening with moisture and climate of Rapa Nui, one must not dismiss the largest volume of water surrounding Rapa Nui, the Pacific Ocean. Rapa Nui, lat. (27° 9S and 109° 26W) is an isolated island located 3700 km west of the Chilean coast and 4100 km east of Pitcairn. Although seemingly isolated on the surface, the Pacific Ocean is very geologically active. Also found in the surrounding waters of Rapa Nui is surface coral *(Pocillopora* and *Porites*) living sea creatures that grow similar to trees in that they have growth rings. The coral can be dated and are very useful when attempting to recreate climate and sea surface temperatures (Mucciarone and Dunbar, 2003). Coral as with ostracods in freshwater contain calcium carbonate shells that retain stable oxygen isotopes.

Rapa Nui lies within the southeastern Pacific subtropical gyre. Because of the low frequency of ship traffic near the island, instrumental sea surface temperatures (SST) data has been limited to no older than 1981. The island is the farthest east in the Polynesia triangle, and is located in the descending limb of the Pacific Walker Cell. It is in a location where sea surface temperatures may or may not influence the Southern Oscillation and where El Nino events result in a signal that is captured by coral oxygen isotopes.

In May of 2003, Genz and Hunt released their data concerning El Nino/Southern Oscillation and its correlation with Rapa Nui Prehistory. What they concluded was the following:

> "ENSO records and their documented teleconnections are presently of no help as a proxy in reconstructing a climate history for the island, as they might be elsewhere in the Pacific Islands (e.g. Hawaii). Nonetheless, while likely independent from ENSO, the data show that rainfall on Rapa Nui is highly variable and unpredictable. This rainfall pattern, in concert with variable wind and its effects of evapotranspiration, made agricultural productivity on Rapa Nui subject to great uncertainty."

It is the surface coral growing around the island that will be very useful in the recreation of climate patterns for Rapa Nui. Analyzing calcium carbonate (coral) is a well-established technique for determining sea surface temperature in the stable oxygen isotopes as well as inferring precipitation. What we intend to find are similarities and trends between the inferred moisture from the isotopes and the inferred moisture found through the plant species analysis of the lake sediment. But it is the differences between them that will show human induced changes in moisture on the island.

Present state of knowledge in the field as compared to this research proposal

Palynology

In order to understand the significance of this research project we must compare to what has previously been found at Rapa Nui. At one point it was believed Rapa Nui to never have had trees and lacking woody vegetation, as noted in Roggeveen's notes of 1722, Gonzalez and Cook in 1777 and La Perouse in 1778. Cook mentioned in his memoir that he saw "woods" in the distance that may have been *Sophora* Toromio, a plant that survived in Rano Kao until the 1950s (Heyerdahl and Ferdon, 1961). Supporting evidence can also be found in (Orliac, 2000) that determined the disappearance of the forests by the change from wood charcoal to grass charcoal around 1640A.D. through the excavation of archaeological sites.

Over time with sediment studies and pollen analysis, it was discovered that the island was in fact sub-tropical and covered by a palm species similar to the Chilean wine palm (Figure 5) capable of growing up to 6 ft. 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* (Figure 4) and *Triumfetta semitriloba*. Another important indirect indicator of a forest was the presence of an extinct Achatenelid (land snail) that is dependent on forest for their survival (Kirch and Christensen, 1991).

Dating of the cores by John Flenley (1984) was conducted by bulk sediment and showed numerous anomalies. Improving this work by using a technique of pollen extraction developed at Massey University by Christine Prior, new dating can be determined by pollen fraction that should be more satisfactory.

Flenley quotes from Birks and Birks (1980) that the use of intuitive methods of vegetational reconstruction rather than modern pollen rain and modern analogue vegetation makes impossible any application of transfer junctions for the reconstruction of former climates. Therefore Flenley used indicator species with ecological preferences to compare climate inclinations such as cool – warm, moist – dry, mesic – stressed. Pollen evidence from the base of the cores dated to near 26,000 yr BP suggests vegetation of a fluctuating climate, while 12,000 yr BP was probably cooler and drier than the present (Flenley, 1991). However, up to this point no attempt has been made to infer climates of the past 1500 years during which human impact has affected the pollen record.

As recently as 1998 paleolimnological research at Rano Raraku and the other crater lakes was largely limited to palynology with the work of the first sediment cores by the Heyerdahl's Norwegian team in 1955 and Flenley & King (1984) and Flenley et.al. (1991). Radiocarbon dates acquired were still seen as questionable by Kamminga & Cotterell, and anomalous by Butler, Prior and Flenley (2004) in current literature not yet published.

Before 1990 aquatic biota had not been studied. In 1990, the Gent University Expedition to Easter Island published descriptions of diatoms (Cocquyt, 1991), rotifers by Segers and Dumont in 1992 and micro crustaceans (Dumont and Martens, 1996). Dumont in 1995 analyzed his freshwater sediment cores for macrofossils and made determinations of introduced species at certain time periods due to their abundance in the lake water. He showed that the sub-fossil content was low in species richness, and supported the previous notions that the island was poverty bound in biota.

Although controversial in his theoretical assertions, Dumont concluded that they found 38 of 70 extant species, in the cores from Rano Raraku, one sponge, one cladoceran and one ostracod. He also argues that totora did not appear in the record before the 14th century and must have been introduced by humans. Diatoms were not totally restricted to modern sediments, but were rare in older profiles. In the *Journal of Paleolimnology*, Dumont (1998) published his profile of cadocera, ostracoda, palm pollen, grass pollen, sponges and diatoms from the cores at Rano Raraku. He makes a claim that the presence of ostracoda and cadocera did not occur before human introduction by the Europeans. This is questionable as most of these species have worldwide distribution and may have come from different locations. Dumont hypothesizes that the introduction of these ostracods also occurred at the same time of *moai* cessation around A.D. 1350. However most of the archaeological evidence disagrees with the dating, stating that *moai* were being sculpted in the late 1600s (Heyerdahl and Ferdon, 1961). What we find of Dumont's work, just as Heyerdahl, is that it does not follow the common thinking of what is to be believed to have happened at Rapa Nui, leaving open ends for arguments and more hypothesis to be formulated from their findings.

Climate and human occupation
In support of a fluctuating climate model, Hunter-Anderson (1997) suggests a geo-climatic model be used to explain the demise of Rapa Nui's palms. As expressed by H.P. Bailey in 1964, a Temperateness Index indicates the degree in which mild climate warmth changes. Comparing an average annual temperature to an average annual range of temperature can determine deviation from a locale's moderate warmth on a daily to yearly basis. Hunter-Anderson suggests that the loss of palm forests on Rapa Nui could in fact be due to the Little Ice Age of the 1700s. That subsistence farming could be in harmony with one's surroundings and not in fact have decimated the island as supposed by the common thinking and evidence found only in soil cores.

Ferren MacIntrye of the Environmental Change Institute at the National University of Ireland wrote in 2002 of the curious coincidence of 535AD. His theory holds that "Rapa Nui was not reached directly from Southeast Asia, but by island hopping, with the last departure point somewhere much closer, such as the Marquesas or Pitcairn." Rapa Nui was settled for the same reason that Madagascar was settled, and about the same time according to Levison et.al (1973), intentionally rather than randomly of 3-way trips, in which exploration preceded colonization, so that many islands would be known, and probably visited, long before settlement.

Another theory introduced at Rapa Nui by Henri Dumont and his team of scientists in 1995-1998 attempted to reconstruct aspects of the history of Rapa Nui over the last 4-5 centuries based on the study of a core from Rano Raraku Lake. He used microfossils of plants and animals, including insects, to identify five distinct sediment zones. Based upon this classification, Dumont argues there were 2 major human occupations on the island. The earliest was from South America in the second half of the 14th century and the second wave was by early Europeans such as Captain James Cook in 1774 or by Jacob Roggeveen in 1722. Dumont's analysis consisted of magnetic information, pollen, diatoms, chrysophyte stomatocysts and fossil plant pigments, which he claims, synchronize South American contact with the cessation of *moai* quarrying.

According to Roger C. Green's multi-disciplined research, he has made inference to the settlers of Rapa Nui as being from the Mangareva sphere (Marutea-Mangarevan-Temoe-Pitcairn-Henderson island region). Descendants of these people sailed from Rapa Nui on to South America circa 1100AD and returned with the sweet potato and bottle gourd. Distribution from here followed to Hawai'i and New Zealand. This hypothesis, contra Heyerdahl states that it was the Polynesians who made contact with South America and then returned for their 40 day sail home to the west. Green also states that "Easter Island was not settled just once and therefore remained isolated," but rather the interaction to both East and West was just less repetitive or continuous than elsewhere in Easter Polynesia (Stevenson and Haoa 1999:5).

Thor Heyerdahl wrote in his "Reappraisal of Alfred Metraux's Search for Extra-Island Parallels to Easter Island Culture Elements," in the Rapa Nui Journal March 1997, that Metraux's study was exhaustive and left no stone unturned. In his effort to trace down a specific area within Polynesia from where the Easter Island culture elements might have come, he found none. With the most vigorous attempts at proposing presence on Easter Island with plants such as sweet potato, manioc, gourd, totora and Chile pepper. And it is Heather and Kirch in 1991 that found evidence of sweet potato on Mangaia island in Polynesia dated to AD1000. Heyerdahl ends his summary with a quote from Landon "…now that the long-concealed evidence of manioc on Easter Island has been brought to light, the notion that the island was the point of entry into eastern Polynesia for a sizable array of American plants must be seriously considered along with all that that might imply."

Langdon himself wrote in the same Rapa Nui Journal, March 1997, "solely on the basis of Behren's account of the islanders' skin colors and Mrs. Routledge's confirmation of its accuracy one would scarcely expect the prehistoric Easter Islanders to have been descended from a single boat load of Polynesians who reached the island in the first millennium of the Christian era. Yet that is the basic assumption of most Polynesianists (e.g. Fischer 1993: 228). No one has seriously argued for two separate prehistoric migrations from Polynesia, but evidence does exist for two separate ones from South America.

Using coral for oxygen isotope analysis
Previous assessments about the amount of Rapa Nui coral state that it was scarce (DiSalvo et al., 1988). Hubbard and Garcia (2003) conducted a follow-up preliminary assessment of the coral reefs of Easter Island. Before this report it was believed that cold-water temperatures, the harshness of the waves and the distance from other coral larvae suppressed coral growth and diversity.

DiSalvo et al. (1988) conducted a quantitative survey of coral distribution and concluded that a coral cover of 0.04% for *Pocillopora damicornis* and 0.34% cover by *Porites lobata* (Figure 8) were present near Anakena beach. Based on these results, Hubbard and Garcia conducted a follow-up in 1999. They report that coral is variable in occurrence, but it is generally much higher than previously reported. An interesting fact is related to the succession of coral. Where once algae and urchins were seen as a negative effect on coral regeneration, it may in fact be part of the process of the development of the current species.

> "One of the authors (MG) has noted over the past 20 years that the urchin populations tend to move from site to site around the island, decimating the algal population at one locale and then moving on. Highest coral was usually associated with a modest community of short, fleshy algae and a lesser number of grazers." (Hubbard, 2003)

Information from the latest publication from Stute et al. (1995) can help in determining a regional climate picture for Rapa Nui. In M. Stute et.al, "Cooling of Tropical Brazil (5°C) During the Last Glacial Maximum," he states that it is a matter of controversy if the LGM in tropical South America was drier than today. However, it should be noted that quantitative paleo-temperature estimates derived from low-elevation pollen records are problematic in confirming this, but pollen records from the lowland Yucatan, and lowland Panama and southeastern Brazil, are consistent with the temperature change of 5° to 8° C.

Stute's noble gas method of testing C^{14}, C^{13}, H^2, O^{18}, tritium, major ion chemistry, alkalinity, temperature, conductivity and oxygen of land source aquifers show a 5.4°C glacial cooling for tropical Brazil and the southwestern United States at a latitude of 29°N to 38°N and is consistent with snow-line and vegetation zones shifts in South America at a latitude up to 40°N. He also states:

> "On the basis of this evidence, it appears that for the continental Americas the latitudinal temperature gradient during the LGM was similar to that today and that a broad zone from 40°S to 40°N had cooled more or less uniformly by at least 5°C."

Besides noble gases tested by Stute et al. (1995), the data on Sr/Ca ratios and ^{18}O from Barbados corals also suggest a SST change of about 5°C at 15ka BP to confirm supporting evidence within latitudinal changes.

On the basis of combined evidence, it seems possible that the glacial tropical oceans bordering the Americas were significantly cooler than they are today. The shift in noble gas temperature occurred at about 10,000 years ago (10ka), the time of the glacial-Holocene transition. With the coral isotopes, we can build Rapa Nui into the picture of what was happening on the East side of

Polynesia and determine if in fact it was acted upon by the same forces that cooled the oceans 3000 km to the east.

Societal impact of climate change

"The present is the key to understanding the past," quoted from James Hutton, geologist in 1785 and to understand how and why climates change, we have to invoke a corollary to Hutton's view: The past must be used to understand the present. (deMenocal, 2001)

Little is known about the societal impacts of longer period climatic excursions. Without knowing the full range of climatic variability at time scales of a few decades to a few millennia, it is difficult to place our understanding of modern climate variability, and its socioeconomic impacts, within the context of how Earth climate actually behaves, both naturally and as a result of anthropogenic increases of greenhouse gases.

Water availability, rather than temperature, is the key climatic determinant for life in semiarid expanses across the planet (deMenocal, 2001) and it is water that is also the critical element to understanding the isolation of the people and species on Rapa Nui. Understanding what was happening with the moisture on the island will be one more piece of the puzzle.

William F. Ruddiman wrote in 2003 about the anthropogenic greenhouse era beginning long before the last 150 years and the industrial revolution. In this study he stated that decreases in the CH^4 concentration gradient between Greenland and Antarctica indicate that the late Holocene CH^4 increase came from north-tropical sources rather than from boreal sources near the latitude of Greenland (Chappellaz et al., 1997; Brook et al., 2000). Chappellaz et al. (1997) concluded that the increased tropical CH^4 emissions since 5000 BP could have come from natural or human sources, or some combination of the two.

Second, evidence from palynology, archaeology, geology, history, and cultural anthropology shows that human alterations of Eurasian landscapes began at a small scale during the late stone age 8000 to 6000 years ago and then grew much larger during the subsequent bronze and iron ages. The initiation and intensification of these human impacts coincide with, and provide a plausible explanation for, the divergence of the ice-core CO^2 and CH^4 concentrations from the natural trends predicted by Earth-orbital changes.

The hypothesis advanced here is that the Anthropocene actually began thousands of years ago as a result of the discovery of agriculture and subsequent technological innovations in the practice of farming. This alternate view draws on two lines of evidence. First, the orbitally controlled variations in CO^2 and CH^4 concentrations that had previously prevailed for several hundred thousand years fail to explain the anomalous gas trends that developed in the middle and late Holocene.

Finally, Lamb (1977) has argued that cooler Little Ice Age climates caused famine and depopulation, as well as increased incidence of disease. Ruddiman's study comes to nearly the opposite conclusion: plague outbreaks caused major population reductions and at the same time contributed significantly to cooler climates.

Objective of the research, expected significance and general plan of work

Human culture is as much a result of as a cause of its environmental change. In order to determine the sequence of events and the chronology of a changing ecosystem there needs to be a comparative assessment of proxies both on land and in the sea to determine human influence. One crucial problem is how to link climate change, environmental degradation and social evolution. The objective then of this research project is to create a moisture profile that is radiocarbon dated, placed into a new climate history and calibrated with the existing archaeological record. The focus of this research is to core two of the three crater lakes of Rapa Nui, beginning in March 2005.

In March, Candace Gossen, co-PI, David Feek, of Massey University and colleague of John Flenley, and a local Rapa Nui archaeologist will spend three weeks coring the crater lakes Rano Kao and Rano Raraku. Rano Kao being the priority is a deep freshwater lake of unknown sediment depth. On the surface is a continuous *totora* reed mat consisting of *polygonum* and *scirpus* that is 3 meters deep with approximately 8 meters of anoxic water beneath. In the past Flenley (1991) cored the lake to 20 meters total depth. These cores provided 11 meters of detritus for sediment analysis. This research project will be a pioneering effort to core the center of Rano Kao that has never been attempted. Using a D-section corer and the Livingstone technique of coring, we will obtain multiple 40mm diameter cores at Rano Kao and Rano Raraku between the depths of 20 and 40m of sediment lending back to interglacial time periods. We will also use an echo sounder to graph and detail the bottom Rano Kao to determine shape and depth of sediment as in 1997 D. Mann provided much detail of Rano Raraku with his echo sounder.

The coring equipment will be shipped by boat from New Zealand to Tahiti then flown to Rapa Nui, with the same return trip once fieldwork is concluded. We will be transporting (50 meters of rods, and 100 meters of casings) in a box made of 6mm plywood that is 1.2m wide, 3m long and 100mm deep. This box can be dismantled on arrival and will be converted to a working platform for the raft. In the box will be the coring equipment. On completion we can use the plywood to make a case to hold the collected cores for shipment home. The equipment also requires a floating device to navigate the lake surfaces that are risky and dangerous since the reed matting is spongy. Two dingies will be required for the humans and extra miscellaneous equipment. Total coring load expected will be 1.3 kg/m on the upper cores and 1.5 kg/m on the lower cores.

The crater lakes and use of palynology since Heyerdahl and Ferdon (1961) has been a useful tool in recreating the chronology of deforestation, the introduction of new plant species, and climate change. More recently in the last 20 years with the work of (Cocquyt, 1991; Dumont 1996; Flenley 1984 and 1991; Mann et al, 2003; Peteet et al, 2003) lake sediment cores from the island crater lakes have created a more detailed picture of the sequences of events. Still there is a need for more evidence to: 1) secure dating, 2) establish a chronology of events beginning with human arrival, 3) establish what the climate was like before, during and after human colonization, and 4) determine the impacts of deforestation on local climate.

Through palynology work we will core the lakes and detail what the ecosystem looked like pre-human settlement, during and after cultural collapse. Although determining the first human arrival by measuring pollen changes is of dispute, as it is well known that a small number of people have been found to coexist successfully with their natural environment without causing noticed degradation in the archaeological or palynological record. This ecological footprint changes with increasing population or changing climates, and it is this point of reference that will be documented in the pollen reconstructions.

Once the cores arrive in New Zealand, this researcher will analyze them over the course of 6 months at Massey University. Working with John Flenley using standard palynological techniques (Faegri and Iversen, 1961) and (Tomlinson, 1984) we will build upon his pollen work of 1984 and 1991. Flenley states in his letter of support attached to this project proposal that “The work proposed by Ms. Gossen will serve to confirm or otherwise my palynological work which was done 20 years ago with rather widely spaced sampling. Since then we have pioneered the extraction of pollen-rich fractions by flotation techniques and with a newly introduced automated technology that welcomes Ms. Gossen into my laboratory and that our skilled coring technician Mr. David Feek will be available to help her obtain the necessary samples.” In order to obtain greater detail we will sample on average 5cm sections of the cores from Rano Kao that will give detailed intervals of 50-100 years. Never before has this amount of detail been disclosed on the environment of Rapa Nui. The objective is to magnify generational details of the last 2000 years. Also significant events of distinct flora changes as it is noted by species change, and species preference to specific climate conditions, will build upon what Flenley began 20 years ago.

Specific species will be identified to determine common, extinct and endemic plants that have either been transported to the island or were present during pre-human settlement. Radiocarbon dates will be obtained in the process to reestablish some questionable dates (Butler, Prior, Flenley, 2004; Mann et al., 2003). There is $3,000 dedicated to radiocarbon dating as well as another $2,000 granted by The Easter Island Foundation to this research that can be used for further dating and data analysis. At current time there are outstanding grants asking for more data analysis monies to expand sample testing.

Also in the sediment cores moisture specific species such as ostracods, diatoms, sponges, and fungi will be identified and used for isotope analysis to recreate a temperature and moisture profile before, during and after cultural collapse. This portion of the research will occur simultaneously while at Massey University by this researcher alongside Kevin Butler, Quaternary Researcher/Bioarchaeologist who has worked with Flenley on some of the Easter Island cores, whose specialty is palynology and is director of the pollen lab at Massey University. The ostracoda samples, useful in isotopic analysis, recreating temperature and moisture profiles, will be sent to David Murriacone director of the Stanford University Earth Science Lab for further analysis in exchange for data sharing. (see letter of support attached). Upon arrival back into the USA, this researcher will spend an unspecified amount of analysis time in the lab at Stanford alongside Murriacone and Dunbar comparing data found in the coral analysis as well as the ostracod 018 data found in the new soil cores.

In a previous study conducted by Rob Dunbar in 1997 at Rapa Nui (Mucciarone and Dunbar, 2003) drilled coral cores at 7 offshore sites surrounding Easter Island (Figure 7). In this preliminary data, they established that they could expect to measure 500 years of El Nino episodes as well as collect historical climate data through surface coral (*Pocillopora and Porites*). This preliminary data established and funded a full NSF grant to continue coring at Rapa Nui beginning March 2005.

Simultaneously coring at Rapa Nui, this researcher will be coring the crater lakes of Rano Kao and Rano Raraku while Dunbar and his group will be scuba diving to select samples of surface coral. The coral will be analyzed for stable oxygen isotopes, which is a reliable method in creating climate profiles (Mucciarone and Dunbar, 2003). Using the data from the calcium carbonates in the soil cores and from the coral we will attempt to correlate both pre-human occupation on Rapa Nui through current era. This analysis will be able to show what the sea surface temperatures (SST) were surrounding Rapa Nui as well as a temperature and precipitation history. This proxy measure will be an important base comparison to test ambient moisture for the region as stipulated by the coral samples, and moisture inferences from the pollen analysis and ostracoda of the soil. By comparing the analysis whatever differences are found could be human induced, but more acceptable as a tool to understanding the forces that were acting on this small little island in a remote part of the South Pacific that influenced the peoples of Rapa Nui.

The objective of the third and final part of this research proposal is to form a partnership and collaboration of data sharing that will assist in creating a more comprehensive understanding of the water world of Rapa Nui.

One long-term goal of this project is to establish a working relationship with Rapa Nui scholars in the field such as John Flenley, Kevin Butler, David Feek, Rob Dunbar, and David Mucciarone. Working together on this study will establish a good solid ground for further research on Rapa Nui, the South Pacific, Polynesia and many lake scenarios around the world and those scholars working in recreating climate/culture changes.

Advancing discovery- *Learning objectives and documentation*
This dissertation project offers an opportunity to include a local archaeologist on the coring team. In this learning exchange we can teach the archaeologist lake coring techniques and leave the island with them being able to know and explain the process of this scientific method. A longer-term goal is to partner a relationship and set up an observation laboratory where school children, researchers and tourists will document the conditions of the lakes so that they may observe and create a written history of the changing conditions of water levels, plant growth, sediment consistencies, on-going processes of climate change, and human interactions.

Most importantly the knowledge that is gained through this research must educate and inspire the local people of Rapa Nui. It must not seem invasive and shall leave the island with more tools and information than before we came. During our stay on the island we will hold community meetings to present the process and findings as well as listen to feedback and concerns from the local people. A classroom field trip might be intriguing for the school age student and aspiring archaeologists as well.

This research will take a traditional written method of publishing results both as a dissertation document to fulfill University requirements, but will fulfill obligations to publish material in journals like Science, Journal of Paleolimnology, Nature, Easter Island Journal, National Geographic and more to be able to reach the general public and wider scientific audience. Good education products are those that are short excerpts published in paper form compiled into edited books. This research will be edited to a short form and offered as teaching materials for all school ages.

Physical collections will be analyzed at Massey University and Stanford University offering a collaborative interaction on an international scale.

Summary
Human culture is as much a result of as a cause of its environmental change. In order to determine the sequence of events and the chronology of a changing ecosystem this dissertation research has proposed a multi-proxy and interdisciplinary approach tying together archaeological, environmental and geographic information asking specifically of Rapa Nui: Did the island's moisture climate change? And if so what caused this?

One crucial problem is how to link climate change, environmental degradation and social evolution. The objective then of this research project is to create a moisture profile by geographic sampling through palynological analysis that is currently lacking. It would also reconstruct aspects of the climate that are not known by using lake species and coral that are radiocarbon dated and placed into a new climate history that is calibrated with the existing archaeological record focusing on events over the last 2,000 years of Rapa Nui existence.

Potential impacts of this study are enormous and address not only the small island of Rapa Nui but also important topics in world prehistory and broad implications that promote interdisciplinary science to help understand the relationships between environmental change, resource use and human decision-making.

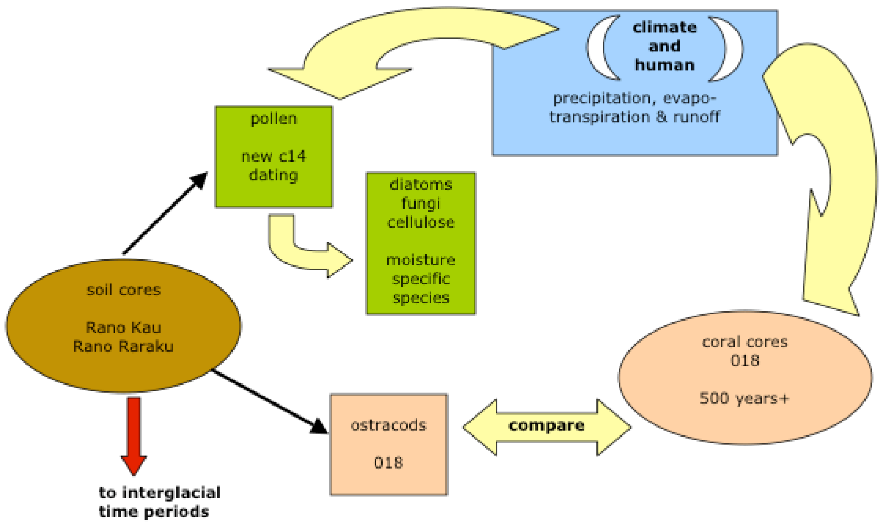

Diagram 1 - theoretical layout of research

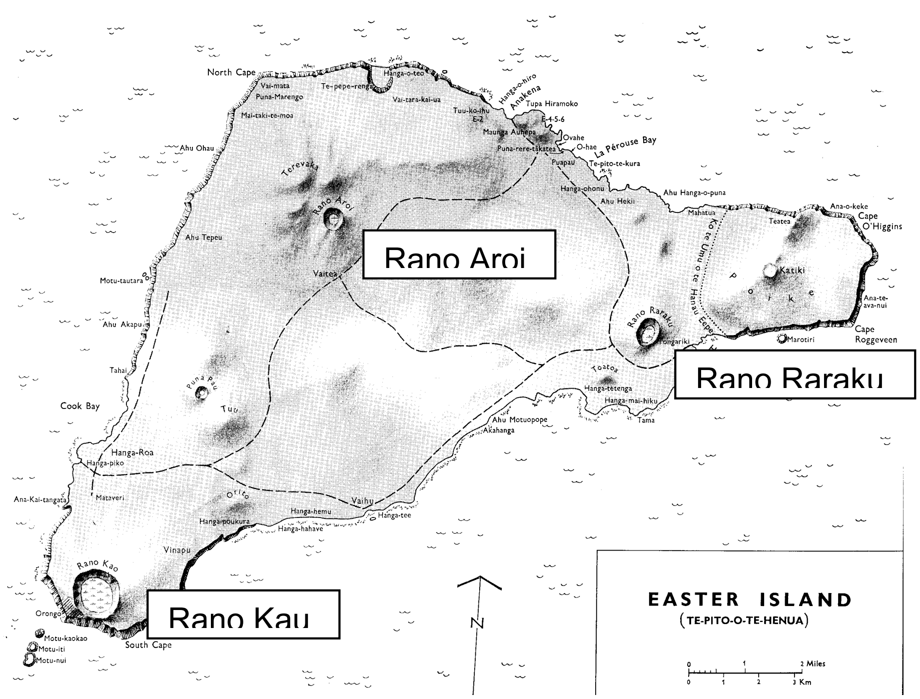

Figure 1. Illustrated aerial map of Rapa Nui showing the three crater lakes.