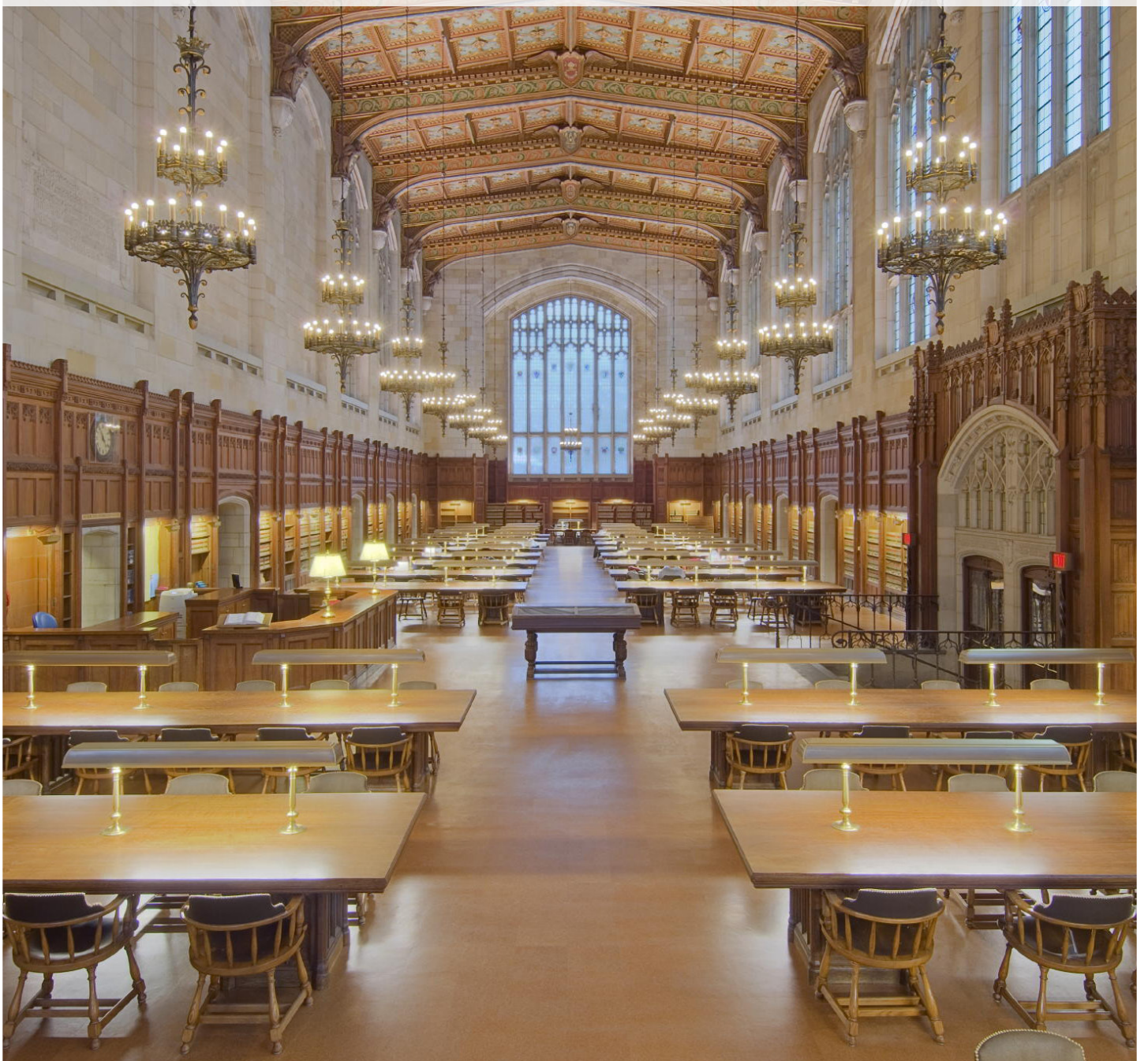




University of Michigan Undergraduate Research Journal

Issue 7, Spring 2010



Letter from the Editors

Dear Readers,

The UM Undergraduate Research Journal is proud to present the Fall 2010 Issue, which represents the seventh consecutive year that we have successfully published the work of outstanding undergraduate student researchers. UMURJ aims to present research papers that reflect the rigorous academic pursuit of inquiry and understanding across all disciplines. UMURJ continues to pursue its unique mission as the only entirely student-run organization dedicated to promoting the communication and exchange of ideas by showcasing undergraduate academic research of such breadth and depth.

This past year our editorial staff has worked hard to improve the quality of the journal. We strove to ensure that each research article published in this issue represents work that is interesting, relevant, novel, methodically sound, and well written. In addition to the research papers submitted by the UM Undergraduates, our publication contains faculty interviews conducted by our staff members on pertinent topics in research and society.

For this issue, we have continued to solicit the assistance of UM faculty members, many of whom are considered leading experts in their respective fields, to guide the peer-review process within UMURJ. We would like to extend a special thanks to the faculty members who so generously contributed their time and insight this year.

We dedicate this journal to the future endeavors of our fellow undergraduates. We hope that this volume will inspire future undergraduates, as it has inspired us, to ask new questions, seek new answers, and develop a passion of knowledge and its pursuit.

On behalf of the entire 2009 and 2010 UMURJ Editorial and Production staff, we thank you for taking the time to read the Fall 2010 issue. It is only with your readership and the immeasurable support we receive from the UM community that empowers us to produce and distribute the journals.

We hope that you enjoy reading about the phenomenal work that has been produced by the undergraduate researchers who are published in this issue of UMURJ and will join us in celebrating their achievements.

Sincerely,
Bhargavi Sampath and Yezi Peng

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Industrial Pollution: Contamination of Surface Water & Human Health in Veerapura, Bangalore

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ABSTRACT

Water quality of Lake Veerapura near Bangalore, India has deteriorated due to uncontrolled dumping of industrial waste. Lake Veerapura receives water from rainfall and industrial effluent streams and may be connected by underground aquifers to bore wells in Veerapura village. Researchers analyzed the extent of water pollution and possible health effects based on chemical analysis of water samples and interviews with 19 families living in Veerapura. Samples were collected from industrial effluent streams, Veerapura lake, and surrounding bore wells. Two sample sets were collected over one month and analyzed at the Karnataka State Pollution Control Board (KSPCB) laboratory for potability and heavy metals. Quantitative results showed that 1) industrial effluent streams violated KSPCB industrial waste standards 2) lake water contained contaminants common to effluent streams 3) bore well water exceeded ISO drinking water standards for hardness. The interviews demonstrated that most families purchased drinking water from the public water supply because they considered bore well water unpotable. The families who had used bore well water in the

past for drinking or bathing complained of muscle weakness, diarrhea, fever, and skin irritations. They also observed that water formed a cloudy film after boiling and corroded the metal containers used to store the water, supporting the quantitative results demonstrating the hardness of the water. Data from this study will aid the Veerapura community and the Society for Voluntary Action, Revitalization, and Justice (SVARAJ) in their efforts to improve the quality of Lake Veerapura and surrounding water resources available to Veerapura residents.

INTRODUCTION

Over the past two decades, India's economy has grown dramatically and has sustained an accelerated growth rate averaging at 7% since 1997. Yet, despite this rapid economic growth and industrialization, India still faces many infrastructural and social problems and 25 % of the population lives below the poverty line¹.

With increasing urbanization and industrialization, Indians are facing even more problems in the form of increased exposure to environmental hazards. Some recently established environmental risks in India include microbial contamination of water, air pollution, arsenic and exposure to toxic metals, pesticides or other industrial wastes. While these exposures are severe and are estimated to account for up to 2/3 of the economic costs associated with environmental health damage in metropolitan cities, there is little research to characterize environmental risk factors and drive prioritized policy changes to improve public health².

1 CIA-World Fact Book, 2009, 12 Feb. 2010.

2 Hu H, Balakrishnan K. The environment and health: an emerging area of research in India. *Indian J Med Res.* 2005;121: pp711-715.

This study is a preliminary evaluation of an area of industrial pollution in the Doddaballapur Industrial Area near Bangalore, India. The Doddaballapur Industrial Area consists of three groups of industries including the Karnataka State Small Industries Development Corporation (KSSIDC) and two sets of larger industries in the Karnataka Industrial Area Development Board area and an Apparel Park consisting of textile dyeing, washing and printing as well as finishing. Nearby and downstream of these industries is Veerapura village.

Villagers in Veerapura rely mainly on bore wells ranging in depth from 80 to 200 ft to provide water for their livestock, food preparation, and household use. However, the recent growth and expansion of industries in the area has led to increased disposal of untreated effluents and sewage into streams feeding Lake Veerapura. The lake is a shallow lake which at its deepest, after the monsoon season, is 2.5 meters. It is sustained by rain water and deposits from sewage. It is possible that the pollution of Lake Veerapura can pollute soil and adulterate underground aquifers feeding into the bore wells used by villagers. Recent studies by the Department of Mines and Geology have demonstrated that the aquifer system near Go Go Exports, nearby Veerapura, had been contaminated over a radius of 1.8 kilometers.

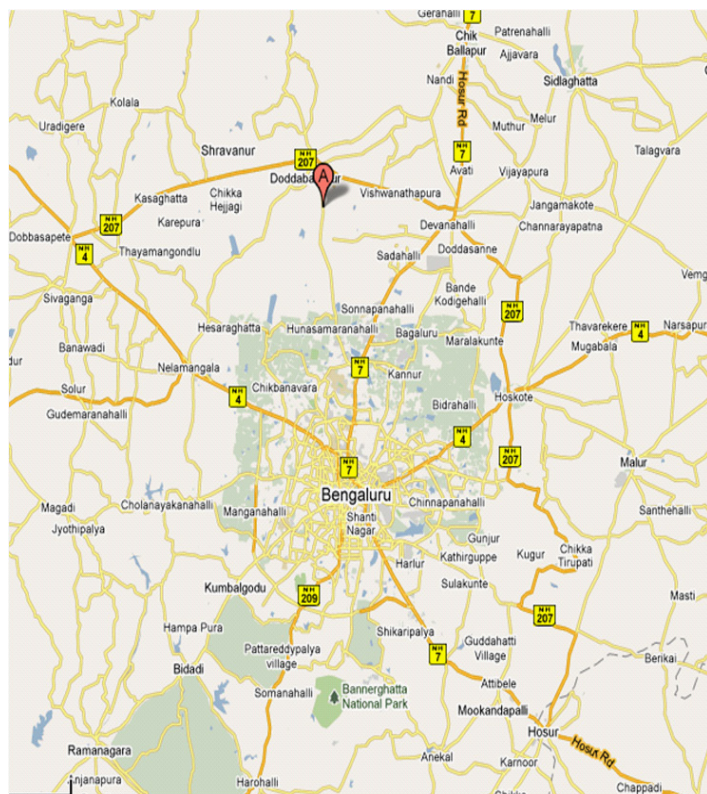
The aim of this study was to assess the composition of the industrial effluents, the quality of the water in Lake Veerapura and determine whether the bore well water adheres to International Organization for Standardization (ISO) standards for drinking water. Sixteen samples including industrial effluents, lake water, lake sediment and bore well water samples were analyzed. Additionally, we interviewed Veerapura residents about their opinions concerning water availability, safety and their health.

METHODS

Samples

Two sets of samples were taken. Each set contained 4 lake water samples, 4 lake sediment samples, 3 industrial effluent samples, and 5 bore well samples (refer to Figure 1 and 2). Four 1L

water samples and four 500g adjacent soil samples were obtained from the perimeter of the lake. Lake water samples were obtained roughly 1 meter away from shore from the surface of the lake. It should be noted that a larger central water body was present at the time of sampling than is represented in the Google image in Figure 1 due to an outdated satellite image and increased monsoon rains. We were unable to obtain a water sample from the center of the lake, however, it is recommended that one such sample should be collected. Each soil sample was obtained on the lake shore border at 2 to 3 inches depth immediately adjacent to each lake sample. Three 1L effluent samples were taken from the industrial area at a drainage juncture near TATA industry and CIPSA-RIC. Two of the effluent samples contained contaminants from different parts of the large industrial area and one may have contained contaminants from the small industrial area across the street. One effluent sample was obtained from a downstream combined-flow location.



Source: Google Maps

Figure 1: Locations of Doddaballapur Industrial Estate with respect to Bangalore (labeled Bengaluru in map).



Source: Google Earth

Figure 2: Locations of samples. Only 1 marker is shown for the 3 effluent samples, which were taken at a drainage junction near TATA industry and CIPSA-RIC.

Handling and Processing of Samples

Samples were collected in the morning on May 20th, 2008 and May 27th, 2008 and delivered to the CPCB laboratory within 3 hours from the time of collection. Lake samples were stored in 2L polystyrene containers. Soil samples were stored in 1 quart plastic bags. Biological samples were stored in sterilized glass bottles provided by the CPCB lab and Dissolved Oxygen samples were collected in 300 mL glass containers and treated with Sodium Azide and Manganous Sulfate immediately.

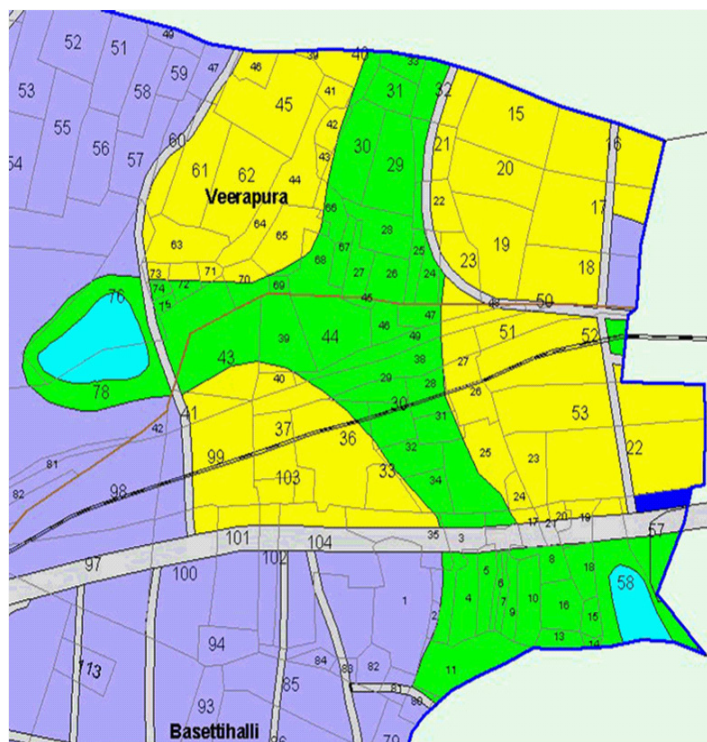
Interviews

Interviews were conducted with families residing in Veerapura Village with the aid of two translators, converting either from Kannada to Telugu and Telugu to English or Kannada to English. Nineteen representatives from different families were interviewed. Families were interviewed from three groups, those living adjacent to the lake, south (upstream) or north (downstream). A convenience sampling of all families that were available and consented to participate was performed.

Survey Design and Rationale

The interview questionnaire first characterized interviewee or household representative by

age, gender, and household size. The purpose of these questions was to allow for personal introductions, to make interviewees more comfortable with researchers and to encourage more thoughtful answers to the later questions. The questionnaire then asked if the drinking water supply was obtained from a private bore well or a public water supply. The purpose of this question was to look for any common water supply sources between the interviewed families. Then interviewees were asked to qualitatively describe their drinking water in terms of taste, color, and presence of particulate matter before and after boiling or filtering. The purpose of these questions was to obtain a qualitative description of the drinking water that might indicate the presence or unusual levels of certain types of compounds or a high level of hardness. Finally, interviewees were asked if and why they were or were not satisfied with the quality of their drinking water. The interview questionnaire was designed with the guidance of Raja Rajeshwari, SVARAJ Research Officer.



Source: Bangalore Intl. Airport Area Planning Authority
Figure 3: Approximate sampling locations for bore well samples. The Panchayati bore well is located beyond the border of the map, past bore well sample 4.

Water Sample Analysis

The two sets of water samples were analyzed at the Karnataka State Central Pollution Control Board (CPCB) laboratory under the guidance of Mr. Raghavendra Instrumentation used for these experiments was donated by the World Bank. All analyzed water samples were graded based on the Primary Water Quality Criteria for Various Uses established by the CPCB in Table A, except the parameters for which no tests or reagents were available at the lab to perform the experiments. Effluent samples were compared against the General Standards for Discharge of Environmental Pollutants in Table B. Lake water and bore well samples were compared against ISO Drinking Water Standards. A sample was considered to “fail” if at least one of the parameters was violated. However when different levels of water quality had the same requirements for a single parameter, the highest possible grade for that parameter was given. Not all parameters from Table A and Table B were tested due to timing constraints of the project. All parameters from the ISO Drinking Water Standards were tested in lake water and bore well samples because the primary concern of the project was to aid SVARAJ’s endeavors to improve the quality of drinking water for the Veerapura villagers.

Outline of Methods

Thorough descriptions of all procedures and instrumentation used are available from the Karnataka CPCB.

pH

All water samples were analyzed using the digital Mettler Toledo MP120 pH meter. Meter was calibrated first with a solution of pH 7.0 and then with a solution of 4.0.

Conductivity

All water samples were analyzed using the digital Mettler Toledo MP120 Conductivity meter. Meter was calibrated with a 0.1N KCl solution with an expected conductivity of 2.38 mS.

Turbidity

All water samples were analyzed using

Nephelo turbidity meter. The instrument was calibrated with distilled water at 0 NTU and refrigerated concentrated acetate solution at 40 NTU.

Chemical Oxygen Demand (COD)

All water samples were analyzed for chemical oxygen demand. 5 mL 0.25N KCr_2O_7 and 15 mL concentrated sulfuric acid were mixed in COD sample tubes and control tube. Mercury (II) sulfate was added to each tube to remove chloride interference. The catalyst silver sulfate was added to each tube. 10 mL of water sample was added to corresponding COD tube and 10 mL distilled water was added to control tube. If a color change from yellow to green occurred while adding sample, sample addition was stopped, the amount of sample added was recorded and distilled water was added up until 10mL was reached. The samples were shaken vigorously to dissolve any yellow precipitate and then heated for digestion. After 2 hour digestions, 40 mL distilled water was added to each tube and allowed to cool to room temperature. Finally, samples were titrated against 0.05N ferrous ammonium sulfate (FAS) using 3 drops of Rantem Ferrion as indicator. The end point was noted when solution turned from blue to brown. A Metrohm 665 Dosimat dosimeter was used to perform the titration. COD was then calculated according to the formula:

$$\text{COD} \left[\frac{\text{mg}}{\text{L}} \right] = \frac{(\text{Control titration volume} - \text{Sample titration volume}) \times 10,000}{\text{Control titration volume} \times \text{Sample titration volume}}$$

Where,

$$10,000 = 5\text{mL } \text{KCr}_2\text{O}_7 \times 0.25\text{N } \text{KCr}_2\text{O}_7 \times 8 \text{ valency} \times 1000\text{L}$$

Total Hardness

All water samples were analyzed for total hardness. The samples were prepared by aliquoting 10 mL of each sample into a conical flask with 2 mL of ammonia buffer solution and three drops of Erichrome Black T indicator. The mixture was titrated against 0.02N EDTA until a pink to blue color change was observed. Total hardness was calculated according to the formula:

$$\text{Atomic Calcium} \left[\frac{\text{mg}}{\text{L}} \right] = \left(\frac{\text{Titration volume} \times 1000}{\text{Sample volume}} \right) \times 0.4$$

Atomic Chloride

Bore well samples were analyzed for atomic chloride (Cl⁻). 25 mL of sample was titrated manually against 0.0282N AgNO₃ with 2 drops of K₂CrO₄ indicator until color changed from yellow to brick red. Atomic chloride was calculated according to the formula:

$$\text{Atomic Chloride } \left[\frac{\text{mg}}{\text{L}} \right] = \left(\frac{\text{Titration volume} \times 1000}{\text{Sample volume}} \right)$$

Alkalinity

Bore well samples were analyzed for alkalinity. 25 mL of sample was mixed with 2 drops of methyl orange solution indicator. Mixture was titrated with dosimeter against 0.02 sulfuric acid until yellow color changed to orange. Alkalinity was calculated according to the formula:

$$\text{Alkalinity } \left[\frac{\text{mg}}{\text{L}} \right] = \left(\frac{\text{Titration volume} \times 1000}{\text{Sample volume}} \right)$$

Dissolved Solids

Bore well samples were analyzed for dissolved solids. The initial mass of glass crucibles were recorded with a digital weighing machine. 50mL of sample was poured into glass crucible and placed in a hot water bath for 2 hours and then transferred to hot air oven for another 1.5 to 2 hours until all water had evaporated. The crucibles and dried residue were cooled to room temperature in a dessicator and then weighed again. Mass of residue was measured and level of dissolved solids was calculated according to the formula:

$$D.S. \left[\frac{\text{mg}}{\text{L}} \right] = (\text{Mass}_{\text{final}} - \text{Mass}_{\text{initial}}) \times 1,000,000$$

It was expected that dissolved solid content would be about 65%-70% of the conductivity reading and this estimation was used in deriving the dissolved solids content for the first set of samples.

Sodium Absorption Ratio

All water samples were analyzed for sodium absorption ratio. The flame photometer was calibrated with known solutions of 0, 20, 40, 60, 80, and 100 ppm sodium and samples were either directly read or diluted before being used for analysis.

Heavy Metal Analysis

All water samples were analyzed for presence of the following heavy metals using the GBC Avanta (Version 1.32) Atomic Absorption Spectrometer: copper, lead, zinc, nickel, total chromium, hexavalent chromium, cadmium, iron, and manganese. In the case of hexavalent chromium, if no total chromium was detected within the sample, analysis for hexavalent chromium was not performed. The analysis for water samples was performed by CPCB staff.

Ammonical Nitrogen

50 mL of each sample was placed into a small beaker. The sample was distilled and collected in a second beaker containing 10 mL of boric acid. A 25 mL sample of the distillate was titrated with 0.02N H₂SO₄ and addition of mixed indicator allowed for the visualization of the endpoint which was a color change from green to purple. Free Ammonia is a proportion of ammonical nitrogen that is dependent on the pH. The preliminary test for ammonical nitrogen involves adding two drops of Nessler's reagent to 50 mL of sample and observing whether the solution turns yellow.

Phenolic Compounds

50 mL of each sample was added to a Nessler's tube with 2 mL of ammonia buffer and 3 mL each of aminoantipyrine and potassium ferricyanide. After careful mixing, the presence of a pink color indicates the presence of phenol. In the absence of a color change, phenolphthalein was added to check if the reagents were working properly.

Cyanide

Two solutions were prepared:

1. Chloramin-T-solution: 1 g white chloramin-T powder was dissolved in 100 mL DI water. Prepare weekly and refrigerate between uses.

2. Pyridine Barbituric acid reagent: 15 g barbituric acid dissolved in 250 mL DI water. Add just enough water to wet sides of flask and wet the acid powder. Add 75 mL pyridine and mix. Add 15mL concentrated HCl, mix, and cool to room temperature. Dilute to 250 mL volume and mix until barbituric acid is completely dissolved. The solution is

stable for 6 months if stored in amber bottle and refrigerated. Solution discarded if precipitate was observed to form.

50 mL of each sample was mixed with 4 mL ortho-phosphate buffer, 2 mL of chloramin-T solution and 5 mL of barbituric acid solution. A drop of potassium ferricyanide solution was added.

Nitrates

50 mL of each sample was added to a glass crucible and placed in a water bath for 2 hours to evaporate the water. The remaining precipitate was dissolved by adding 2 mL of concentrated diphenyl sulphonic acid, followed by 2 mL of DI water to reduce the concentration of the acid and up to 10 mL of 50 % NaOH to make the solution highly basic. If a yellow precipitate was observed upon the addition of NaOH, the sample was filtered, raised up to 50 mL with the addition of DI water and measured with a spectrophotometer at 540 nm.

Dissolved Oxygen

The samples were collected in 300 mL glass containers and filled slowly to the brim to prevent bubble formation. The sample was then immediately treated with 2 mL of sodium azide and 2 mL of manganous sulfate to precipitate out the oxygen. After collection, the sample was analyzed within 3 to 4 hours. Sulfuric acid was added to dissolve the precipitate. A portion of the sample was titrated with silver nitrate, starch was added as the indicator and titration was stopped when an endpoint of purple to clear was observed.

Biological Oxygen Demand

BOD measurements required that DO be performed for a sample on day 0, after collection and compared with DO measurements taken on day 3 after the sample had been incubated at 37C. Comparing the change in oxygen levels between these three days in the samples versus the controls allowed for the determination of the BOD. The calculation of BOD can be performed as follows:

$$BOD = \frac{((W_1 - W_2) - (C_1 - C_2)) \times 300}{(\text{sample taken})}$$

Oil Sample Analysis

Soil samples were air dried or oven dried for several days before being ground up into a fine powder and sifted. Air dried powder was used for pH and conductivity tests. Oven dried powder was used for organic carbon, sulfate, and heavy metal analysis.

pH

10 g of air dried powder was dissolved in 50 ml DI water and shaken for at least 30 minutes. The pH reading was taken in similar manner as described for fluid samples.

Conductivity

The conductivity readings were taken using the same prepared soil samples for the pH tests.

Organic Carbon

25 g oven dried powder was mixed with 1N $K_2Cr_2O_7$ and 20 ml concentrated sulfuric acid. Then 200 mL DI water and 10 mL orthophosphoric acid and NaCl were added. 1 mL diphenylamine was used as indicator when titrating with 1N ferrous ammonium sulfate. The endpoint occurred when dark blue changed to bright green. Organic carbon content was then calculated according to the formula:

$$\% \text{ Org C} = \left\{ 10 - \left(10 \times \frac{S}{B} \right) \right\} \times \frac{0.003}{0.77} \times \frac{100}{\text{gram sample weight}}$$

where S = ml of FAS titrated for sample, B = ml of FAS titrated for blank.

Sulfate

10 g soil was dissolved in 50 mL water and shaken for a few hours. The mixture was filtered into Nessler's tubes and filtrate subsequently reconstituted up to 100 mL with DI water. 1 to 2 drops HCl was added and heated to a boil. 4N $BaCl_2$ was added until a precipitate formed in the solution. NH_4OH was then added to bring the solution to a neutral pH. The neutral solution was then titrated with 0.25N $K_2Cr_2O_7$ and the endpoint was observed using the external indicator, $AgNO_3$. The sodium sulfate content was then calculated according to the formula:

Sodium Sulfate = $0.0177 \times 100(x - y)$, for 10g sample

Where x = ml N/4 -BaCl₂ added and y = ml N/4 potassium dichromate used in back titration.

Heavy Metals

Soil samples were dried in a drying oven and ground into fine powder with a mortar and pestle. 0.5 g powder soil was added to 25 mL DI water and 5 mL concentrated nitric acid. The solution was boiled down to 15 mL of liquid and resuspended to a volume of 25 mL in DI water. The samples were all analyzed by the GBC Avanta (Version 1.32) Atomic Absorption Spectrometer.

RESULTS

Interview

One family lived immediately adjacent to Lake Veerapura. 15 families lived north (downstream) of Veerapura Lake. Three families lived south (upstream) of Veerapura Lake. Out of the 19 families interviewed, 0 families were satisfied with the quality of water available to their households. 1 family expressed "partial satisfaction", and 18 families expressed "no satisfaction." 10 of the family representatives were female, and 9 were male.

The family living adjacent to Lake Veerapura was the only family to obtain drinking water from a bore well, which may or may not share the same aquifer as Lake Veerapura. 11 out of 14 families obtain drinking water from a Panchayati tanker, while the rest used a private tanker. All 3 families upstream of the lake used the Panchayati tankers as well.

No families reported "no taste" of drinking water. Of the families that explicitly responded to the question, all indicated that the water had a distinct taste. Most reported a salty taste. A majority of the interviewees reported the presence of white film or white precipitate in their drinking water.

In addition to the questionnaire answers, several of the interviewees mentioned illnesses occurring within the last four years that they believed to have been caused at least in part by the poor quality of water including: tuberculosis, muscle/nerve weakness, stomach ache, diarrhea, light fever, hair loss, and rash.

Evaluation of Effluent Samples

The effluent samples failed both the General Standards for Discharge of Environmental Pollutants and the Primary Water Quality Criteria for Various Uses Laid Down By CPCB Class E. The effluent samples were brown, turbid and had a foul odor. Most noticeably, the pH values of the samples (mean=3.58, n=6) were well below the prescribed levels allowed by both standards.

Evaluation of Lake and Bore Well Samples

All the lake and bore well samples failed the ISO drinking water standards. Most notably, the total hardness (Lake: mean=9.462, n=8, Well: mean=13.503, n=8) and contributing ion constituents: calcium (Lake: mean=8.474, n=4, Well: mean=9.275, n=8) and magnesium (calculation only), exceeded permissible limits. However hard water doesn't appear to have adverse effects on human health. Mildly hard water has been associated with a decreased risk of cardiovascular disease, . . . But hard water does make the water less palatable to drink and can corrode storage containers.

The lake samples exceeded ISO turbidity standards. The bore well samples were not tested for turbidity because from observation they appeared to be clear. However the dissolved solids exceeded permissible ISO standards (calculation only). Dissolved solids exhibit a "mineral taste," in water and can corrode metal surfaces. They indicate a high level of dissolved matter that may or may not have harmful health effects in humans. However it may affect plant growth and agricultural irrigation.

Lake samples exceeded ISO permissible limits for sulfate levels (mean=73.3, n=8). Bore well samples exhibited high levels of chloride (mean=15.575, n=8) but were still within permissible limits. Both do not appear to cause significant health problems at the levels present in the samples collected.

Lake samples had high iron content (mean=0.313, n=8). Although high iron content may give water a bitter taste and stain laundry, it is not hazardous to human health.

Lake samples also had high levels of manganese (mean=0.433, n=4), which may cause disease in humans including liver damage. Manganese is not known to cause problems for agriculture or livestock use. Manganese may cause brown stains in laundry and poor tasting water.

Summary of Listed, Measured Values

	Effluent Samples		Lake Samples		Well Samples	
	Mean	N	Mean	N	Mean	N
pH (at 25°C)	3.58	6				
Total Hardness			9.462	8	13.503	8
Calcium (25 mL sample)			8.474	4	9.275	8
Sulfate (mg/L)			73.3	8		
Chloride (mg/L)					15.575	8
Iron (mg/L)			0.313	8		
Manganese (mg/L)			0.433	4		

CONCLUSION AND FUTURE WORK

The effluents released into the storm drain near the large industrial area are highly polluted. These effluents converge into streams that feed into Lake Veerapura and seem to have polluted the lake as well. COD and BOD values for the lake are high and heavy metals that were prominently represented in the effluents were also found in the lake. However, we were not able to establish a relationship between the pollutants in the lake water and the bore well water. This relationship has to be further investigated by studying the seepage of the pollutants into the soil. The drainage pattern of effluent and lake water, the topography of underground aquifers near the industrial area, the lake and Veerapura village need to be determined and combined with data from a larger sample of bore wells of varying distances from the lake in order to characterize how the pollution of the lake water can affect the quality of the well water.

This study provides us with preliminary evidence that helps characterize the extent of the pollution, the quality of the drinking water and provides us with clues as to which parameters to further investigate. We can conclude that the effluent samples are highly polluted and that the surface water in the area has become contaminated as a result. Further investigation needs to be performed over a long period of time make sure that the results are reproducible and to understand how the results could vary seasonally.

The relationship between the drinking water and any possible health effects mentioned by the villagers also needs to be further investigated. In interviews, the villagers spoke with such conviction about the illnesses they experienced after drinking water from the Veerapura area approximately three to four year ago. We were surprised to find that the contaminants present in the well water could not account for the aforementioned health effects but it is possible that other pollutants that were not tested for can account for the villager's statements. Another study should be conducted to investigate the health of the villagers three years ago when the symptoms were manifested. The study should quantitatively determine the number of villagers who became sick, their distance from the water source, the water source they consumed, the type and severity of their illness, etc. Characterization of the health of the villagers three years ago will help us understand what factors could be adversely affecting the health of the villagers.

Our study should be used as a preliminary framework to guide further investigation of the area. Once the reproducibility of our results is verified it will be possible to use the results to protect the land near Veerapura and the health and livelihood of the residents of the area.

NOTES

To read additional appendix materials such as the interview questionnaire, photos of survey sites, and further documentation visit UMURJ.org.

Effects Of Transient Topography And Drainage Basin Evolution On Detrital Thermochronometer Data

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ABSTRACT

Understanding how mountain ranges evolve is important for interpreting their geologic and topographic history. Quantifying topographic evolution is difficult because the rates and processes involved occur over long timescales. Mineral cooling ages may have the potential to quantify landscape evolution. Understanding the sensitivity of detrital thermochronometer data to topography, erosion and other factors allows geologists to use the data to interpret the history of mountain belts. This study focuses on the effects of evolving topography and erosion on the age distributions that would be found in a sedimentary basin below a mountain belt. This study presents results from a series of coupled numerical models (Pecube and Cascade) used to simulate the thermochronometer response to topographic evolution. The thermal histories from rocks exhumed to the Earth surface are used to predict mineral cooling ages as a function of the topographic history of the mountain range. The results of simulations testing different exhumation rates and rates of drainage basin evolution show a signal of topographic evolution in detrital thermochronometer data.

INTRODUCTION

Detrital thermochronometer data have the potential to quantify the history of landscape evolution and transient topography in a mountain belt because topography deflects isothermal surfaces in the crust.⁹ Topography has the greatest effect on the thermal field in the upper few kilometers of the crust, so a thermochronometer with a low closure temperature has the most potential for recording the effects of transient topography.⁹ For this reason, we make predictions for the low temperature thermochronometers apatite (U-Th/He) and apatite fission track. Detrital cooling ages sampled in modern rivers or sedimentary basins are affected by evolving topography, erosion, wildfires, groundwater and other factors that may deflect the geothermal field.¹⁵ It is important to understand the sensitivity of detrital thermochronometer data to these factors in order to accurately interpret the history of a mountain belt. The goal of this paper is to quantify the effects of evolving topography and erosion on the age distributions that would be found in a sedimentary basin downstream of the mountain belt.

Previous work addressing the effect of drainage basin evolution on mineral cooling ages has been limited. A study by Whipp et al. has looked at the effect of changing relief on detrital thermochronometer data in different kinematic scenarios.¹⁵ Rahl et al. evaluated transient erosion rates recorded in detrital data using a one-dimensional numerical model to make predictions for detrital thermochronometer ages.¹¹ Their study confirmed that detrital thermochronology can be used to quantify erosion rates, but did not evaluate drainage basin evolution. Ruhl and Hodges used modern river sediments to quantify erosion rates,

but did not evaluate evolving topography or transient erosion rates, instead assuming steady state topography during the closure interval recorded by the detrital thermochronometer ages.¹³ Brewer and Burbank compared $^{40}\text{Ar}/^{39}\text{Ar}$ muscovite age distribution data with predictions of a numerical model that assumed a time invariant erosion rate.⁴ Brewer and Burbank also evaluated the influence of faulting geometry on detrital ages using numerical models of erosion in collisional orogens that assumed topographic steady state.⁵ Studies by House et al. and Ehlers et al. were more observational in scope and sought to document observed cooling age signals of changing topography.^{9,6}

This project complements previous studies by attempting to quantify the influence of drainage basin evolution on detrital thermochronometer signals observed in sedimentary basins. Our approach utilizes a series of coupled numerical models including a landscape evolution model, 3D thermal model and a cooling rate dependent age prediction model. The results of simulations testing different exhumation rates show that there is potential to find a signal of topographic evolution in detrital thermochronometer data.

MODEL SETUP

This study utilizes coupled thermokinematic and surface process models to simulate topographic evolution and calculate the cooling history of rocks exposed at the Earth's surface. We employed a version of the thermokinematic model Pecube (Braun, 2003) modified to predict cooling age distributions in drainage basins. Figure 1 illustrates the parameters and processes included in the numerical models. Details of each of the models are as follows.

Thermokinematic model

We utilize the thermokinematic numerical model Pecube (Braun, 2003), modified to predict age distributions for different thermochronometers.¹⁵ This model was used to simulate the processes of topographic evolution potentially recorded in thermochronometer data from sedimentary basins. The model has two main components: a kinematic model and a thermal model. The following sections describe the numerical model setup and the free parameters.

Kinematic model

The kinematic model simulates rock transport from erosional exhumation. We focus on a scenario of imposed uniform vertical uplift with varying exhumation rates. The kinematic and

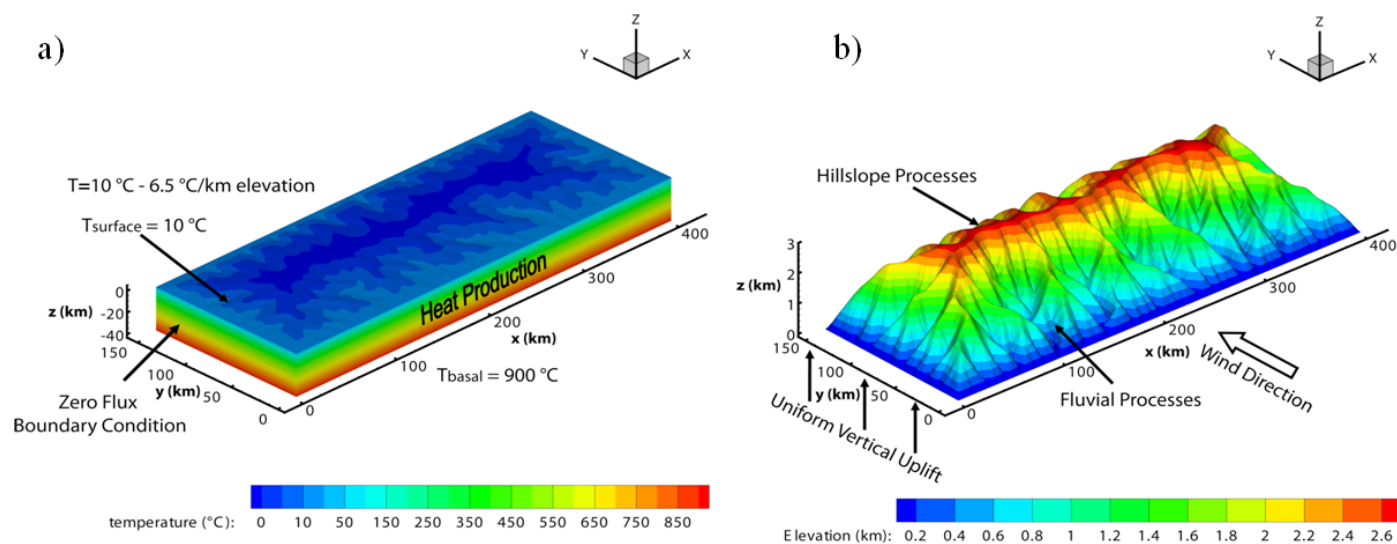


Figure 1. (a) Thermal model setup includes a zero flux boundary condition, basal temperature of 900°C , heat production and surface temperature boundary condition of 10°C . The atmospheric thermal gradient is $-6.5^{\circ}\text{C}/\text{km}$ of elevation. (b) The surface process model includes hillslope and fluvial erosional processes and imposed uniform vertical uplift from the coupled kinematic model. The model also includes spatial climatic variations such as wind direction, temperature and precipitation.

thermal models were started 50 Myr prior to the surface process model to produce a crustal block with an initial age distribution. The range of initial input velocities considered was 0.00 – 0.1 mm/yr for the first 50 Myr of the simulation (70-20 Ma). All the simulations discussed in this study used an initial uplift velocity of 0.10 mm/yr. After the initial crustal age distribution was created, the couple thermokinematic and surface process models tested rock uplift velocities in the range 0.25 – 1.5 mm/yr for the last 20 Myr of the simulation (20-0 Ma).

Thermal model

The background thermal state of the crust is determined by heat flow into the base of the crust, the surface temperature, and thermal physical properties such as thermal diffusivity and heat production. In tectonically active areas this background thermal field is perturbed by erosion and sedimentation, topographic evolution, faulting, and lateral variations in thermal properties. Pecube solves the transient advection-diffusion equation using the advection velocity from the kinematic model. The primary output of the thermal model is the thermal history of rocks exposed at the surface, which is used to calculate the cooling-rate dependent apatite helium and fission track ages following the approach of Ehlers et al.⁶

Surface process model

Topography in orogens develops as rivers cut channels into the bedrock and rivers and hillslope processes, such as diffusion and mass wasting, carry material downhill. Topography and climate form a coupled system controlling erosion rates and orographic evolution. The topography causes orographic precipitation by forcing upward movement of warm, moist air. Climatic variables in turn control river discharge, determining fluvial erosion rates which control the development of topography. The surface process model Cascade calculates the temporal evolution of topography as a function of tectonic uplift and hillslope and fluvial erosion, following the approach of Willett et al. and Braun & Sambridge.^{1, 14} Model free parameters include climatic variables and material properties

that influence fluvial and hillslope processes described in Table 1.

Hillslope processes are represented by diffusion, and the change in height in time due to hillslope erosion is calculated using diffusion in two dimensions.¹⁴

Fluvial erosion depends on the discharge in the river which is calculated using spatial variations in climate, including orographic precipitation and feedback, following the approach of Roe et al.¹² The change in height over time due to fluvial erosion processes is calculated from the dimensions of the channel and the discharge.¹⁴

The hillslope and fluvial erosion equations are combined with an applied uniform uplift u , giving an equation for the change in height,

$$(1) \frac{\partial h}{\partial t} = u + k_d \left(\frac{\partial^2 h}{\partial x^2} + \frac{\partial^2 h}{\partial y^2} \right) + \frac{k_f}{a} \sqrt{Q} \frac{\partial h}{\partial t},$$

where k_d is a diffusion constant and h is the height at the location x,y at time t , w and l are the width and length of the channel, k_f is the fluvial erosion constant and Q is the discharge where a is a proportionality constant accounting for the stream width.¹⁴

The primary output of the surface process model is the change in elevation across the domain as a function of time. The changing topographic surface, and hence erosion rates, are used as the top boundary condition in the thermal model such that mineral cooling ages are calculated as a function of the topographic evolution.

RESULTS

A wide range of thermal and surface process parameters were considered (as shown in Table 1) to simulate the sensitivity of thermochronometer systems to different rates of topographic evolution. For simplicity a subset of these results is presented, for the cases where the thermochronometer signal of topographic evolution was most pronounced. Influence of uplift on drainage basin evolution Figure 2 presents the results of two simulations with exhumation rates of 0.25 mm/yr and 1.00

mm/yr. The primary feature here is the change in relief over time. In both scenarios the relief grows through time and eventually reaches equilibrium. The evolution of topographic relief is presented in Figure 3. For example, Figure 2 shows that after 2 Myr of uplift the topography has a relief of 0.6 km

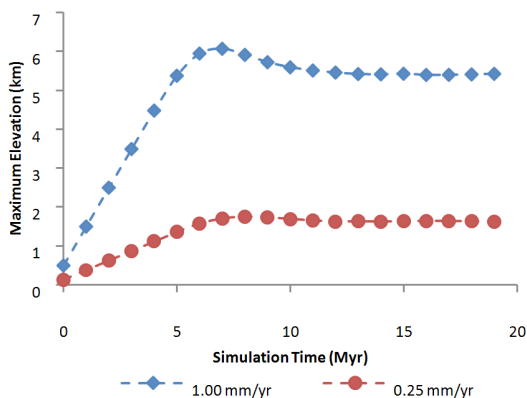


Figure 2. (Above) Effect of varying rock uplift rates on topographic evolution. Results of simulations with rock uplift rates of 1.00 mm/yr and 0.25 mm/yr are shown. Both reach steady state topography between 5 and 10 Myr.

for a simulation with an exhumation rate of 0.25 mm/yr. After 7 Myr, simulation a) has reached steady state and relief stays constant for the next 13 Myr (as seen in Figure 3). Figures 2 and 3 also show that relief grows more quickly for faster exhumation rates. Simulations at 0.25 mm/yr and 1.00 mm/yr both reached steady state topography at approximately 7-10 Myr, but the 1.00 mm/yr simulation reached a steady state elevation more than three times that of the slower rate. The change in basin size as topography evolves is the second important feature displayed in Figure 2. Inspection of Figure 2 a) shows that drainage basins roughly double in size between 2 and 5 Myr. The rate of basin evolution is primarily controlled by the efficiency of fluvial processes. Rates of fluvial erosion depend on local channel slopes, discharge,

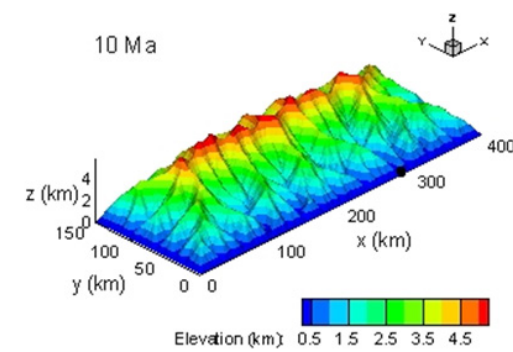
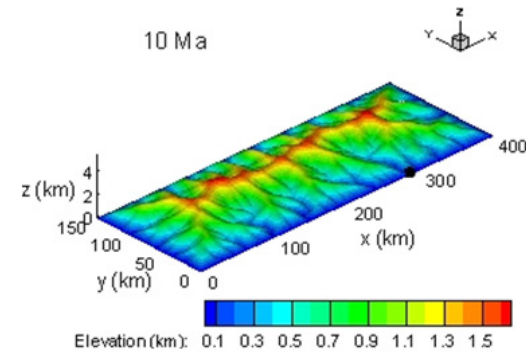
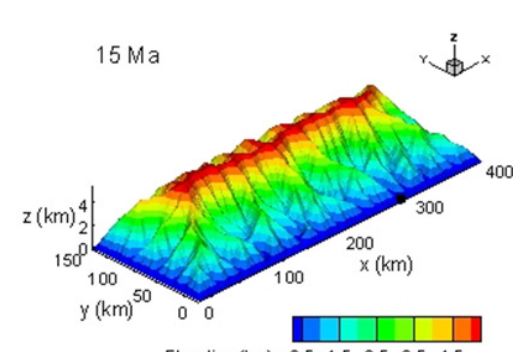
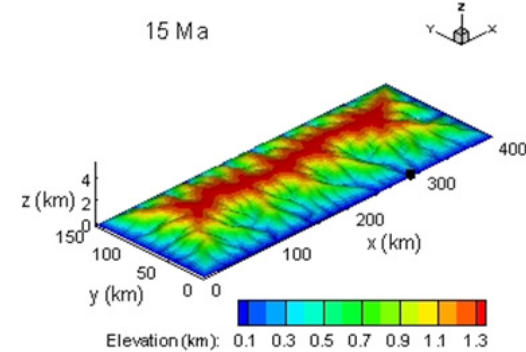
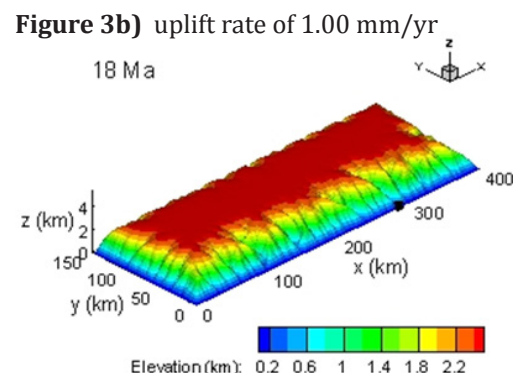
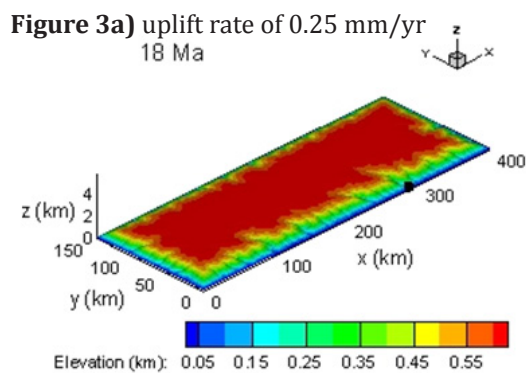


Figure 3. (Right) Influence of rock uplift rate on drainage basin evolution. Contour plots of elevation are shown at 18 Ma, 15 Ma and 10 Ma for rock uplift rates of (a) 0.25 mm/yr and (b) 1.00 mm/yr. (a) The topography reaches a steady state with an elevation of approximately 1.7 km between 15 and 10 Ma. (b) The faster exhumation rate causes the topography to develop more rapidly and the steady state elevation of approximately 5 km is reached by 10 Ma. The black points mark the location of catchment 1394 which will be discussed in detail in section 4.

and climate. Higher uplift rates generate steeper channel slopes and a higher orographic precipitation and therefore erode more quickly.

Figure 4a illustrates the development of the catchment labeled with a black point in Figure 2. The catchment develops rapidly early in the simulation and reaches a steady state by 15 Myr. Figure 4b shows the migration of the drainage divide as topography develops. At the beginning of the simulation (0 Myr) the drainage divide is symmetric at 50% of the domain and when the topography reaches equilibrium the divide has advanced to between 60 and 70% of the domain. Migration of the drainage divide indicates that the size of the drainage basin is changing the most during the first approximately 7 Myr and then reaches steady state.

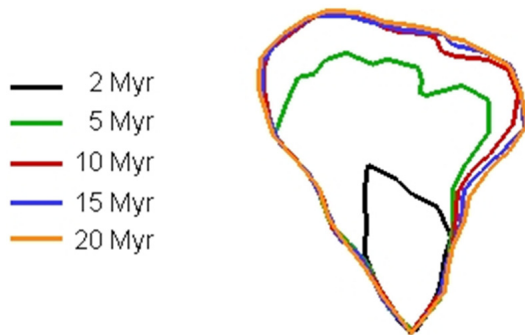


Figure 4a. Schematic of catchment development for catchment 1394 (indicated with a black point in Figures 2 and 5) in the simulation with uplift rate 0.25 mm/yr. The catchment grows rapidly at the beginning of the simulation (between 2 and 5 Myr), and reaches a steady state by 10 Myr.

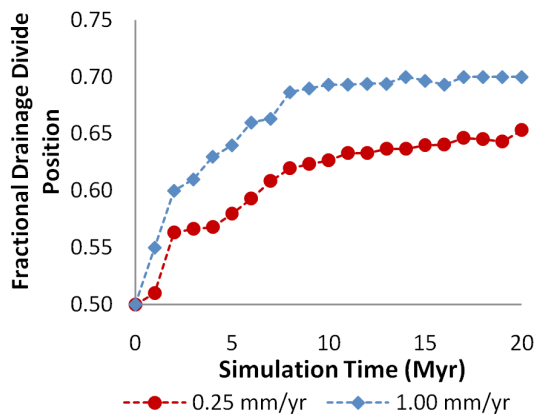


Figure 4b. The fluvial drainage basin divide position as a function of simulation duration. Results are shown for simulations with rock uplift rates of 0.25 mm/yr and 1.00 mm/yr. In both cases, the divide position advances until it reaches equilibrium. This average divide position of all basins was measured from $y=0$ as it progressed across the domain.

Influence of drainage basin evolution on cooling ages

Figure 5 shows the apatite (U-Th/He) ages of rocks exposed at the surface during two simulations. The first order trend in Figure 5 is that the age range varies in time. For example, 2 Myr into the simulation of topographic evolution (18 Ma), the age ranges are small (~ 7 Myr for 0.25 mm/yr) and not much topographic relief has developed (0.5 km for 0.25 mm/yr, from Figure 3). As relief grows, the age ranges increase. Eventually the age ranges begin to decrease in time. The second order trend that appears in Figure 5 is an age range dependence on exhumation rate. For example, a simulation with a fast uplift rate of 1.5 mm/yr reaches a maximum age range for rocks exposed at the surface at approximately 5 Myr while a simulation with a slower uplift rate of 0.25 mm/yr reaches a maximum age range later at approximately 8 Myr. This can be seen more quantitatively in Figure 6 where the age-range exposed at the surface is plotted as a function of simulation duration. The initial age distribution in the simulation causes the initially large range of ages that then decreases. The largest age ranges coincide with the times of topographic development seen in Figure 2.

DISCUSSION

Rates of drainage basin evolution

Rates of drainage basin evolution are controlled by fluvial and hillslope processes. Climatic effects on river discharge control fluvial erosion, while topographic evolution controls hillslope processes and climate feedbacks. Faster uplift rates cause the drainage basin divide to migrate further across the domain, producing faster drainage basin evolution. Precipitation varies with time due to orographic feedbacks. The topographic and climatic feedbacks in the system control the rate of topographic evolution.

Thermochronometer sensitivity to basin evolution

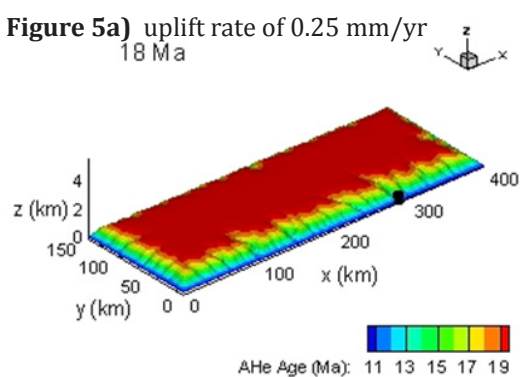
For a measurable signal of transient topography to appear in detrital data, topography must evolve at a time when a large range in cooling ages is exposed. A large age range creates greater sensitivity to the amount of area exposed at the surface

at different elevations, creating greater sensitivity to catchment evolution. For example, Figure 6 shows that the exhumation rate affects the time that the age range reaches a maximum. This suggests that maximum age ranges will occur at different depths in a stratigraphic column, depending on the exhumation rate. This should make it possible to quantify the exhumation rate of a mountain using detrital data. A larger age range exists for a longer period of time for simulations with lower exhumation rates. The conditions for a signal of transient topography include a large age range during topographic evolution and a slow exhumation rate that allows a large crustal age range to exist throughout topographic development.

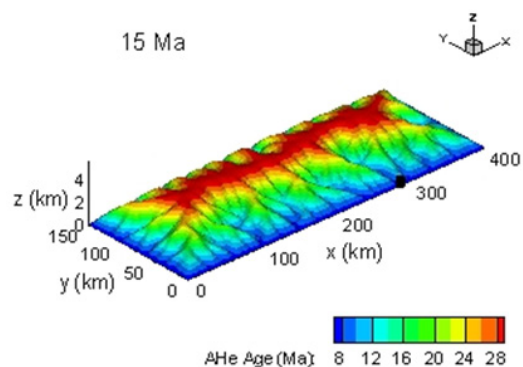
The thermochronometer ages of the rocks

exposed at the surface are used to calculate synthetic cooling age distributions that would be found in a sedimentary basin. The points on the model that contribute to a certain catchment are determined using the D8 algorithm.⁸ An age histogram forms a raw age distribution, with the assumption that every point in the catchment produces sediment that will contribute to the age distribution found in a stratigraphic column downstream.¹⁵ These raw age distributions are then time shifted to account for the remainder of the simulation, during which the sediment continues to age in the sedimentary basin. In Figure 7 we estimate the magnitude of the signal by producing synthetic PDFs of cooling ages in a catchment for a simulation with an exhumation rate of 0.25 mm/yr. The catchment

Figure 5a) uplift rate of 0.25 mm/yr
18 Ma



15 Ma



10 Ma

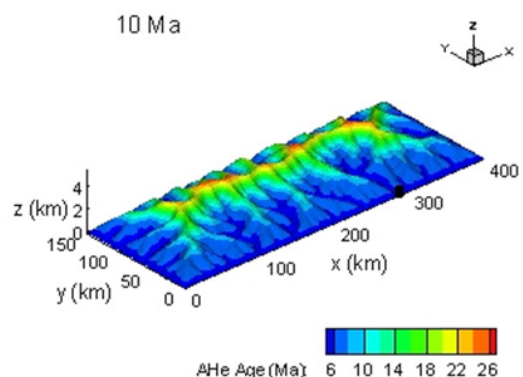
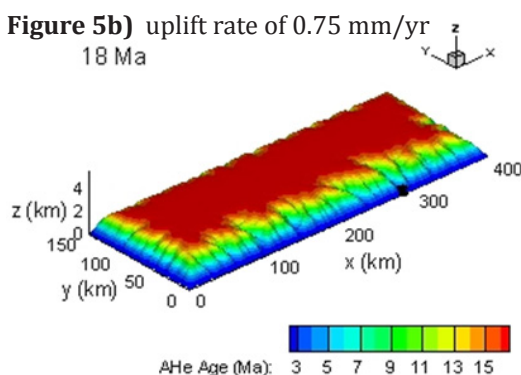
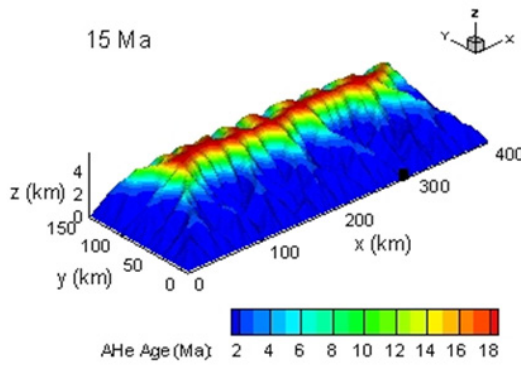


Figure 5b) uplift rate of 0.75 mm/yr
18 Ma



15 Ma



10 Ma

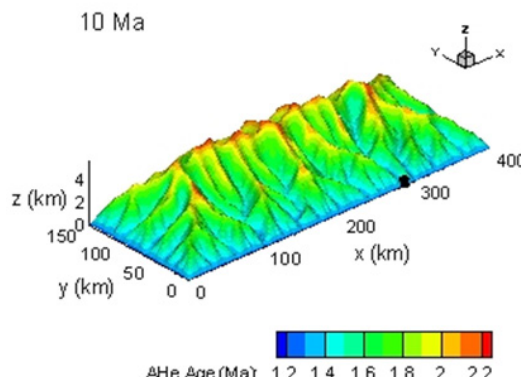


Figure 5. (Left) Influence of drainage basin evolution on apatite (U-Th)/He cooling ages. These plots present the ages of rocks exposed at the surface for three different times and for simulations with exhumation rates of **(a)** 0.25 and **(b)** 0.75 mm/yr. The contour scales give a sense of the age ranges eroding off the mountain at a time in the simulation. The black point indicates the position of catchment 1394, which will be considered in the discussion section.

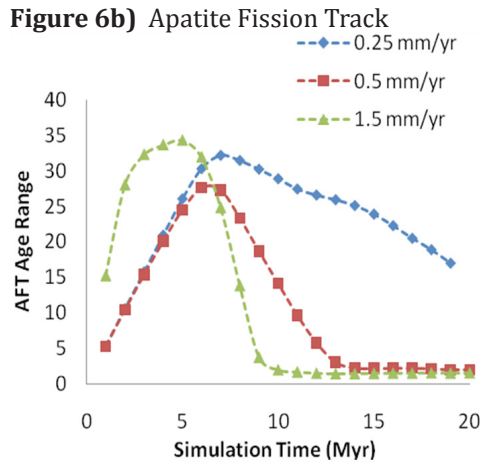
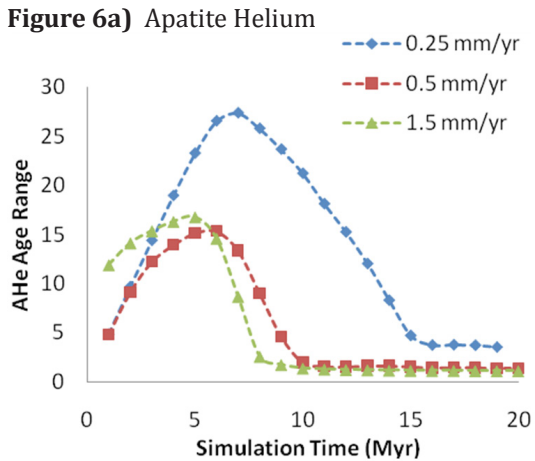


Figure 6. Crustal age ranges over time. These graphs quantitatively illustrate the age ranges shown in Figure 5. **(a)** Apatite (U-Th)/He and **(b)** apatite fission track age ranges of rocks exposed at the surface are presented at different times throughout the topographic development. Results are presented for simulations with rock uplift rates of 0.25, 0.5 and 1.5 mm/yr, respectively. For both thermochronometers considered, the simulation with the fastest rock uplift rate reaches a maximum age range first, followed by the intermediate rate, and then the simulation with the slowest exhumation rate.

Figure 7)

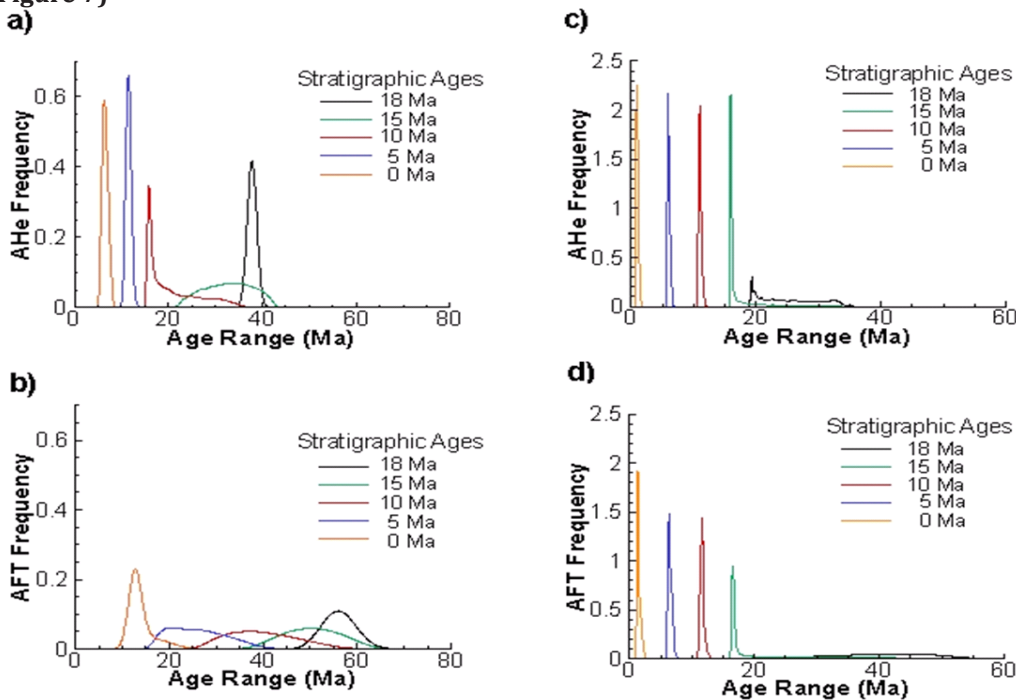


Figure 7. Synthetic probability density functions in catchment 1394 for **(a)** apatite helium ages in simulation m026c with rock uplift rate of 0.25 mm/yr, **(b)** apatite fission track ages in simulation m026c at 0.25 mm/yr, **(c)** apatite helium ages in simulation m030c at 1.00 mm/yr, and **(d)** apatite fission track ages in simulation m030c at 1.00 mm/yr. These plots estimate the magnitude of signal predicted for a PDF of this catchment.

considered is indicated with a black point in Figures 2 and 5. There are two considerations that will affect the fidelity of a signal: 1) Topography must evolve when a large age range exists in the crust, and 2) the inherited age (age range depends on both the uplift rate and the inherited age signal in the crust prior to topographic evolution).

Figure 3 indicates rapid topographic evolution occurs during the first 5-10 Myr of simulations m026c and m030c with uplift rates of 0.25 mm/yr and 1.00 mm/yr. The largest variations in cooling ages in Figure 7 a) occur over the same time period for simulation m026c. This suggests sensitivity to drainage basin evolution. In Figure 7 a), the synthetic cooling age PDFs for 5 Myr and 10 Myr have

large age ranges but very different geometries. Figures 7 c) and d) present the age distributions for simulation m030c, which has a faster uplift rate of 1.00 mm/yr. The age ranges narrow before the topography reaches steady state, creating less sensitivity to drainage basin evolution. For slower uplift rates, a large age range exists in the stratigraphic column for a longer period of time, producing a longer record of drainage basin evolution. However, age range and the shape of the distribution may also be sensitive to the initial (inherited) age distribution. Future studies could focus on understanding how these PDFs differ for steady state topography throughout the entire history as compared to transient topography.

A detrital signal of transient topography requires 1) a large initial crustal age range, 2) slow rock uplift rates ($\sim 0.25\text{-}0.75$ mm/yr), 3) low to medium precipitation rates to keep erosion rates low. If the above conditions are met, then basin evolution will occur at time scales of 5-10 Myr in the simulation and will be accompanied by a large age range in sediments preserved in a basin of this age.

CONCLUSIONS

This study used 3-D coupled thermokinematic and surface process models to analyze the influence of transient topography on detrital thermochronometry. Topographic evolution occurs between 5-10 Myr for each simulation, and the uplift rate determines the steady state elevation of the topography. Slower uplift rates allow a larger age range to exist on the topography for a longer period of time, due to lower orographic precipitation rates and slower erosion. We found that large age ranges in detrital data indicate periods of rapidly evolving topography. The PDFs of age ranges in a catchment showed narrow age ranges early in topographic development and after the orogens had reached steady state topography for a slow uplift rate. For a faster uplift rate the age range disappeared more quickly, before the orogen reached steady state. There is potential to find a signal of transient topography in detrital thermochronometry data from an orogen with a large initial age range in the crust and a slow exhumation rate.

Thermochronometer data from sedimentary basins could be used as a way to constrain paleotopography. However, the remaining issue of inherited crustal age distribution still needs to be resolved.

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Response of Great Lakes Coastal Wetland Plant Communities to Climate Change

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Wetland vegetation along the Great Lakes shoreline has been affected considerably by climate change, water levels, and human activity over time. In order to understand the dynamics of Great Lakes coastal wetlands better, we must discover a relationship between plant communities and climate. This project seeks to establish a relationship using field data collected at Negwegon State Park near Alpena, Michigan. Plants were classified into communities using non-metric multidimensional scaling (NMS) and cluster analysis. Among various metrics used to describe the vegetation data, frequency and importance value of species resulted in the best grouping of the plant communities. Environmental variables tied to climate, such as hydrologic variables, soil characteristics, geological setting, and wetland ages were correlated with plant community composition. Hydrologic variables were the most significant environmental drivers, as identified by correlation with NMS results, and likely will be the most influential in determining trajectories of plant community change. Our discovery supplements current knowledge of plant community response to climate change, and therefore, may assist managers who are making critical decisions for wetland habitat, especially in the Great Lakes region.

eBay Behavioral Game Theory: A Support Vector Model

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Romesh Saigal, PhD

Over the past 15 years, the process of purchasing an item has changed dramatically. Through the creation of online bidding and purchasing on eBay, it is now possible to buy an item with almost no knowledge of the seller or item quantity. This presents the possibility that an item may arrive to the bidder in an unacceptable condition, the item is a counterfeit, or the seller did not even ship the item (Saigal). Auction sites do provide feedback systems to give the buyer an idea of whether or not an online seller is reliable; however, these systems are very flawed. Buyers who are unsatisfied with the item quality often do not give negative feedback for fear that they may receive negative buyer feedback in return (LaPlante). Due to this inflation in seller ratings, the feedback system cannot be used directly to determine seller reliability.

The goal of this project is to formulate equations that will model whether or not a buyer should purchase an item from a seller of a certain rating, and how much the buyer should be willing to pay. Traditional game theory and probability theory methods, including utility functions and the Nash Equilibrium, are applied to model eBay transactions. The derived Nash Equilibrium equation depends on a variable known as α , the probability that the seller is trustworthy. Our goal during the fall and winter semester was to use a multidimensional analysis tool, called a support vector machine, in order to find trend lines that will help us determine a more accurate α . By categorizing and labeling data that has been gathered from eBay, the support vector machine will give formulas that will determine how to find α for an unknown seller. This will be useful not just for the buyer, but the results will also potentially create a form of third party insurance that could be used to protect eBay users from fraudulent transactions.

Ex-Offender Transition Study

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Alford Young Jr., PhD

The Joyce Foundation began the Transitional Jobs Reentry Demonstration to assist former prisoners in finding employment. Statistics show that two-thirds of those released from prison are rearrested, half being within the first three years of release, usually not because they have committed new crimes but rather because they have violated the rules of parole supervision, namely not being able to find a job and maintain a residence (Dan Bloom, MDRC). The goal of this research is to see how former prisoners benefit from the prisoner reentry programs. Ultimately, the research hopes to discover if the program is successful in the readjustment of former prisoners back into a functional lifestyle in society, with steady employment, a place of residence and emotional support. Professor Alford Young, Jr. has interviewed thirty-three participants in the program when they first entered the program and then again a year later, asking them about their employment, self-identity, and how they feel they are viewed in society. These interviews are currently being read over and coded as to what category they fall under, focusing on either the former prisoners' concept of time or identity. They then are analyzed further into subcategories to try to find commonalities and differences among the participants. Once the interviews have been completely analyzed, there will be further evidence on the benefits of the program. This research is still ongoing, and there are no definite conclusions. As of now, the research is looking to code, analyze and develop interpretive themes for the data. The research hopes to draw conclusions on how the reentry programs are affecting their lives after reentering society. However, since it is still in its beginning stages, there is no way to have a projected outcome.

Identification of *Bacillus anthracis* Genes Required for Growth in Blood

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Bacillus anthracis is a pathogen that can remain dormant for a prolonged period of time. Once a host is infected, spores first germinate and begin to replicate within phagocytes, then proceed through the lymphatic system, and finally make their way into the bloodstream. Antibiotics and vaccines previously developed are not effective treatments, resulting in a demand for a more in-depth understanding of how exactly anthrax infects its host, and how it functions once it is inside the host. A greater understanding of the pathogen's virulence can result in new potential drug and vaccine targets. Analysis of gene expression profiles of *B. anthracis* grown in blood yielded a list of potential genes to target in future studies. It is hypothesized that some of these genes are important to the survival of anthrax in the host's bloodstream. The objective of this project is to create mutant strains of *B. anthracis* through homologous recombination, which will lack specific genes chosen from the microarray results. The mutant *B. anthracis* strains will be examined for the ability to grow in blood, and compared to that of wild type *B. anthracis*. Mutant strains that show decreased growth in blood will be further tested for virulence in a mouse model of inhalational anthrax. Mutant strains that show decreased growth in blood and decreased virulence in a mouse model would show that the particular gene knocked out could be used as a potential new target for treatments.

Consequences of Perfectionism Scale: Gender Differences and Associations with Affectivity and Life Satisfaction

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Edward Chang, PhD

The Consequences of Perfectionism Scale (COPS) is a newly developed multidimensional scale involving two factors that assess for perceptions of perfectionism as adaptive (e.g., “being perfectionistic drives me to be motivated”) and maladaptive (e.g., “being perfectionistic hinders me from pursuing my goals”). In the present study, we examined the gender differences of COPS and analyzed the associations between scores on the COPS with scores on measures of positive and negative affectivity and life satisfaction. We also tested the COPS against the Ruminative Response Scale (RRS) to see if it adds to the prediction of life satisfaction and positive and negative affectivity. Results indicated no significant differences in mean levels on the COPS between men and women, and also suggested that the COPS is a better predictor of positive affectivity and satisfaction with life in males compared to the RRS. Overall, findings from the present study provide further evidence of the validity and usefulness of the COPS.

Being a Good Mom, Cricket Style: Do Insects Have Hormone-Mediated Maternal Effects?

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Robin M. Tinghitella, PhD

Numerous studies indicate that animals from diverse groups can influence the survival and success of their offspring via non-genetic, maternal effects in which the environment experienced by the mother is translated into phenotypic variation in the offspring. It is also known that in vertebrates, such as birds, these effects are frequently mediated by the hormone testosterone. While maternal effects are common in insects, they have no such steroid sex hormones. Juvenile hormone (JH), a ubiquitous and important invertebrate hormone that produces several of the same effects as testosterone, is a promising candidate for mediating insect maternal effects. This study seeks to discern the presence of maternal effects – in particular, hormone-mediated maternal effects mediated through JH – in insects, using field crickets as a model system. Virgin female field crickets, *Acheta domesticus*, were randomly assigned to one of two treatments: early mate, in which a female mated for the first time five days post-eclosion, or late mate, in which a female mated for the first time twenty-five days post-eclosion. In both treatments, the females’ eggs were collected three days after mating, and the egg size, number of eggs laid, and the amount of JH in each egg were determined. We hypothesized that females may adjust their reproductive effort depending on female age and male mate quality. For instance, if a female mates for the first time late in her life, she might allocate more of her resources into reproduction, thus resulting in bigger eggs, more eggs, and/or more JH per egg. Alternatively, if a female mated with a preferred male, she might similarly allocate more resources to his offspring than would a female mated to a non-preferred male. If we find evidence for hormone-mediated maternal effects (i.e. the crickets allocate additional JH to their offspring under some circumstances), a follow-up experiment will determine how high JH titers affect the crickets once they are born (by measuring size, competitive ability, and survival, for instance).

The Effects of Androgen Metabolites on Prostate Cancer Growth

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James Rae, MD

Prostate cancer is the most commonly diagnosed cancer among men in the United States. Prostate cancer growth is primarily driven by androgens, and anti-androgens are frequently employed therapeutically. However, resistance to therapy is a common occurrence that is not well understood. Androgens activate the androgen receptor, which induces growth. Testosterone is the primary androgen in men and women, but it is not very potent. It is converted in the body by the enzyme 5 α -reductase to the steroid 5 α -dihydrotestosterone (DHT), which is the active androgen in the body. DHT is further reduced to 5 α -androstane-3 β , 17 β -diol (3 β Adiol) by the enzyme 3 β -hydroxysteroid dehydrogenase (3 β -HSD). 3 β Adiol is a ligand of both estrogen receptor α (ER α) and β (ER β). Despite the fact that 3 β Adiol is an androgen metabolite, it does not bind the wild type androgen receptor (AR). However, it has been demonstrated that the mutated AR is more promiscuous and is activated by a variety of ligands such as androgens, progestins, estrogens, and anti-androgens. My project investigates the effects of androgens and their metabolites on growth in prostate cancer cells. We hypothesize that 3 β Adiol is a ligand of the mutated AR. Further, the generation of androgen metabolites that differentially modulate ER and AR may represent a potential mechanism of resistance to therapy. To examine how androgen metabolites modulate ER and AR we are using growth assays of prostate cancer cells in culture. These experiments may give insight to possible mechanisms of androgen metabolites to resistance in prostate cancer.

Assessing the Effectiveness of Innovations in Undergraduate Anatomy Education

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Ameed Raof, MD

The promotion of undergraduate anatomy education is a rapidly growing trend on college and university campuses nationwide. With this advancement comes the responsibility to monitor the quality of such valuable, relevant education. In its eighth year and sponsored by Dr. Ameed Raof, the project assesses the effectiveness of undergraduate anatomy education at the University of Michigan by conducting survey research on students enrolled in the course Anatomy 403. The project seeks to see how well undergraduate students from many different backgrounds perform in and feel about an upper level science course in the field of anatomy. Surveys are distributed to undergraduate students enrolled in Anatomy 403 two times during each semester, once after the midterm examination and once after the final. These surveys are comprised of a wide range of detailed questions of both the qualitative and quantitative variety. After collecting the surveys and ensuring confidentiality, Microsoft Excel is utilized to compile the data and analyze it accordingly, including comparing it to previous terms in which Anatomy 403 was taught. Ideally the results will provide a good indication of the current quality of undergraduate anatomy education at the University of Michigan; thus far, the figures suggest an overall student sentiment of satisfaction with the Anatomy 403 course, particularly its plastination laboratory component. On a larger scale, the hope is to use the findings to increase students' interest in enrolling in courses on the topic of anatomy, a lifelong learning process that is fully applicable to everyday life.

Bridge to Lung Transplantation Using Atrial Septostomy and Veno-Venous Extracorporeal Membrane Oxygenation

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Robert Bartlett, MD

Pulmonary hypertension often leads patients to develop right ventricular failure and death. Despite conservative measures, patients require lung transplantation. However, one third of patients die while on the waiting list. Atrial septostomy (ASD) has been performed clinically to offload the right ventricle until transplantation; however, shunting of blood from the right to left atrium causes hypoxemia. A novel approach to improve right ventricular failure and maintain normal oxygenation may be the combined use of ASD and extracorporeal membrane oxygenation (ECMO). This study was designed to investigate if a combined ASD and ECMO modality can be an effective bridge to lung transplantation. Using a sheep animal model, a thoracotomy was performed under adequate anesthesia and analgesia to create an atrial septostomy. After a day of recovery, the sheep were placed on veno-venous (VV) ECMO. This involves drainage of blood from the inferior vena cava (IVC), gas exchange through a membrane oxygenator, and reinfusion into the right atrium. After initiation of ECMO, a clinical model of pulmonary hypertension was simulated by banding of the pulmonary artery. Sheep hemodynamics, ECMO flow, and blood chemistries were monitored. Results to date have shown that this combined modality maintains normal cardiac output with acute pulmonary hypertension, however there is slight hypoxemia. It is thought this is related to insufficient ECMO flow due to anatomic factors in sheep that affects double lumen cannulae position. This results in inadequate ECMO flow due to reduced blood drainage from the IVC. Despite drainage complications, these findings suggest that ASD with VV ECMO could be an effective bridge to lung transplantation.

Measurement and Analysis of Advanced Nuclear Fuels for Safeguard Applications

Theresa Willson, tmwills@umich.edu

Jennifer Dolan; Marek Flaska; Sara Pozzi

As nuclear power becomes a more viable resource for clean energy, a need arises for its safe use to our best ability. One problem is related to the spent fuel of reactors; specifically, how it can be disposed of in the most efficient way. One alternative to the disposal of the nuclear materials is to recycle them in mixed-oxide fuels that can then be put back into the reactors, preventing excess of waste. The need for safeguards techniques to accurately characterize such advanced nuclear fuels is therefore in great demand.

This research focuses on detecting and characterizing mixed-oxide fuels using Monte Carlo simulations and measurements performed at the Idaho National Laboratory in June 2009. The mixed-oxide fuels were measured by running a series of tests on two well-defined fuel pins. The fuel pins will be characterized by looking at time-correlated and pulse-height distributions of the measured gamma rays and neutrons. The examination of the results involves finding the pulse-shape of each particle and its time signature for the cross-correlation functions. These developed pulse-height distributions and cross-correlation functions will be compared to simulation results. Once the analysis is complete, conclusions will be drawn as to how accurate the proposed method is to efficiently identify and characterize these mixed-oxide fuels.

Types

- Sciences
 - Chemical, Medical, Psychological
- Engineering
 - Material Science, Civil Electrical
- Humanities
 - History, Languages
- Social Sciences
 - Economics, Political

To Get Started

- Ask your professors about their exciting research
- Search department websites for PI's in your field of interest
- Search the Student Employment Website
- Join or visit the UROP office to streamline the whole process
- Steps for getting an interview:
 - Identify a research project
 - Due diligence: background research and network
 - Send email cover letter and attach a resume

Benefits of Research

- Contributes to the advancement of human knowledge
- Builds a unique set of hard skills and hands on experience
- Helps identify your academic and career interests
- Prepares you for graduate opportunities
- Provides a steady income or academic credit

Looking Ahead

- Summer Opportunities
 - Summer Research Opportunity Program (SROP)
 - Research Experience for Undergraduates (REU)
 - Social Sciences & Humanities Summer Fellowship Programs
 - Summer Biomedical and Life Sciences
- Professors seek research assistants year round

How to Get Involved In Research

Interview of Dr. Ken Warner, *Dean of the School of Public Health*

Prepared by Ana Progovac & Derek Wood

Dr. Ken Warner has been Dean of the UM School of Public Health since 2005. He stumbled upon Public Health from a background in Economics, and his research since that career move has focused on preventing disease and promoting health through economic and policy measures with a focus on tobacco policy. He also worked to initiate and currently teaches the first and only undergraduate Public Health course (HMP 200: Introduction to Public Health).

How would you define public health?

Public health is the set of activities a society undertakes to monitor and improve the health of its collective membership. It has three distinguishing features: a focus on preventing disease & injury, the idea that the “patient” is the entire community (not individuals); and that the “provider” is society (and not individual professionals).

How do you work and interact with other health professionals?

I do this in all kinds of different ways. The people I work with are not all health professionals, but rather people oriented towards health. Tobacco control is the area I’ve worked in most of my career and I was the World Bank’s delegate to the negotiations that put the international tobacco control treaty together (known formally as the Framework Convention on Tobacco Control). That’s kind of at the 30,000 foot level. At the local level I work with folks at the Washtenaw County Department of Health. I also collaborate with senators and legislators in Lansing trying to pass the Smoke-Free Workplace Law. We work very closely with people in Washington, D.C. who are involved with tobacco control organizations. The list goes on...

Are there any roles you feel you’ve taken on as the dean that are very important or different to you?



I relate to a large number of people now about public health much more generally than what I’ve done in the past. People ask me questions about health care reform, and I will typically send them to one of my colleagues in Health Management and Policy who focuses on that subject. I get asked things as if I’m an expert on everything.

I certainly represent the school in many locations where we’re talking about big broad health issues, so a lot of my canned speeches will have references to the health reform debate for example, but I’m always personally leary of trying to over-represent my expertise.

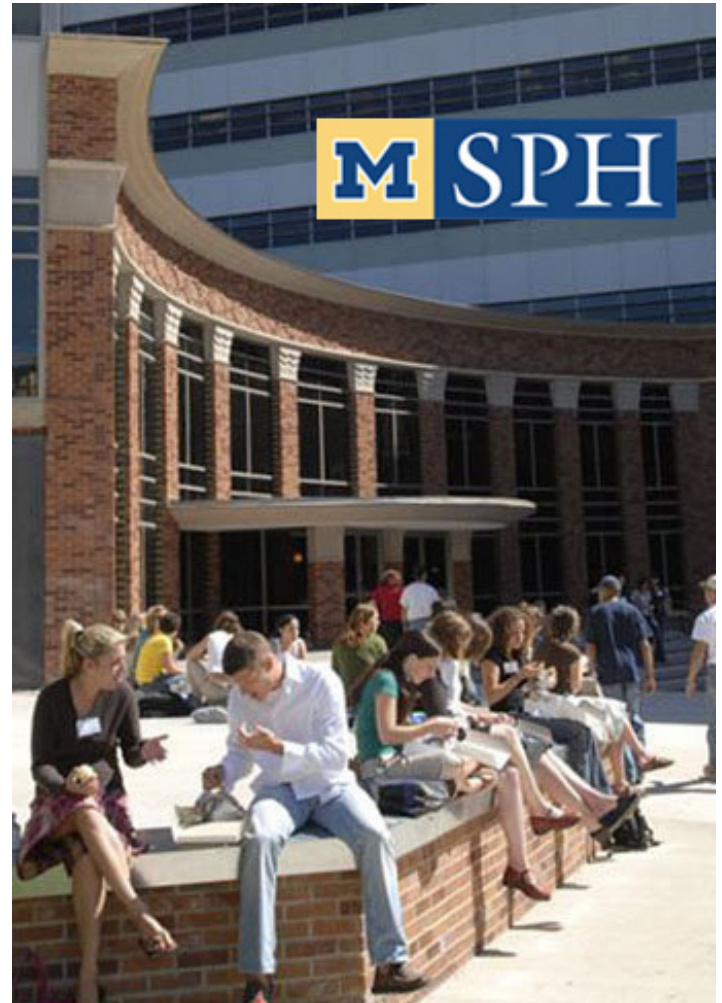
What does someone usually do with a master in public health degree?

Public health is a huge field – if you simply look at the names of our five departments: Health Behavior and Health Education, Health Management and Policy, Biostatistics, Epidemiology, and

Environmental Health Sciences, they themselves are sufficiently different to suggest the breadth of positions and jobs available. We have over 13,000 alums of the school, and they are all over the world doing all kinds of different things. The department I know best is Health Management and Policy. The single most common job that the graduates of this department are engaged in is management positions in health care systems. They typically start out at low to intermediate levels – they may be specifically working in hospitals, they may be working in the central office of large healthcare systems, frequently they’re working in a department within a hospital such as ambulatory care or physical medicine and rehabilitation – they’re getting their first professional experiences in hospital administration. We have a large number of people who work for consulting firms – they’re hired to deal with specific problems. A very large number of our graduates start out with a fellowship for one or two years. We have people who go work in Congress as aides to legislative committees; we have people who go work at the Centers for Disease Control and Prevention (CDC). The corporate sector also hires a lot of our graduates for health policy advice – some pharmaceutical companies in the past years have hired graduates of ours to evaluate new policies coming from Washington D.C. A quarter of our students are PhD students who go on to become researchers. The epidemiologists and biostatisticians do just as the name suggests, as do the health educators.

Coming from a background in economics, what attracted you to the field of public health, and what drew you into tobacco research?

I was in college when my sister developed a rare cancer, which she died from four years later at the age of 21. When I got into graduate school, I just felt kind of impotent about dealing with the situation. I was in economics, and I wanted to do something in health economics that was specifically related to cancer. So I did a dissertation that was related to the use of novel chemotherapies and how that was a quasimarket process, as opposed to the usual market process. When I was looking for



jobs after having spent eight years at all-male Ivy League schools, I decided I wanted to be at a really good, public co-educational research university. There were only three places I wanted to be: Berkeley, Michigan, or Wisconsin, which in those days were the top three. It turns out that there was a job available here at Michigan. Economics is a far more applied field than something such as literature; a lot of other fields exist because they’re intellectually and aesthetically important. Even with a field like economics that focuses on applied work, you’re still playing a pretty theoretical game – it’s basically a very mathematical game, you have to come up with the more sophisticated math models to “beat the other guy.” That’s what I was used to in graduate school, but when I got here I discovered people working on real world problems and it was kind of nifty. Here at the School of Public Health, what most people are doing is relevant to the real world. When I first got involved in tobacco policy research, I got some astonishing real world feedback, and I

was getting involved in things up the level of the Secretary of Health and Human Services. I was very young, just getting into this, and it was all very heady. That all derived from my research. Educationally, I appreciate that the public health students are a good group of people who want to make a difference in the world; they're not there to figure out a way to make a lot of money.

some work study research possibilities, though we typically want to give our own students priority for those. But also, if people are interested in particular areas they should come and talk to our faculty members over here.

Focusing on the specifics of your research career, can you tell us about your research with tobacco policy?

"It's got the technology of cigarette development, the sociology of smoking, the economics, politics, the biology. . . you name it, they're all there, they're all put together, and it's just endlessly fascinating, and I haven't gotten bored with it after 30 years."

Why did you feel it was important to establish the undergraduate class on public health?

First of all, public health is a field that most people do not understand or can easily define. It's not something like law or medicine – no one comes to college thinking 'I'm going to go into public health'. I thought the class could function simply as a device for exposing some undergraduates to the field. I thought and hoped it would be successful in helping to recruit students into the profession and some of them into our School of Public Health. I've been saying we ought to do this for a good twenty years. I finally decided it was time to put our collective money where my mouth has always been and do the class. It's been really fun, and it's a great group of people. We were worried we wouldn't get more than thirty people; we figured undergraduates don't look for public health courses, since all previous public health courses have been for graduate and professional students. All of sudden we started getting flooded with requests, and we filled up quickly. We ordered 140 textbooks and said that was a good place to stop. Next year if this goes well, and there's enough demand, we'll probably open The course up to more students.

How could an undergraduate become involved in public health research?

We have several faculty members here who have UROP students working with them, and that is probably the best way to do it. There are also

I got here in 1972 and I was very fortunate in 1975/76 to get something similar to a post-doctoral fellowship. It gave me the opportunity to go out to the National Bureau of Economic Research at Stanford University to work with Victor Fuchs, who is sort of the father of health economics. I spent a year out there continuing some of the work I had been doing on medical technology, and looking at changes in utilization of surgical procedures before and after the introduction of Medicare and Medicaid in 1965. We wanted to see how much more surgery we were seeing of various types after there was money available for it.

While I was there (having just quit smoking myself after having smoked about 10 years), I picked up a San Francisco Chronicle, and there was an article that stated "Anti-smokers have been wasting their breath." The article argued the anti-smoking campaign had been useless because adult per capita cigarette consumption was not any lower in 1974 than it had been in 1964, the start of the antismoking campaign. About a month later there was another article in the Chronicle, this time saying that a new government survey showed continuing declines in the percentage of adult American smokers. That struck me as inconsistent. I was just starting to get curious as to how to reconcile these when I happened to hear a seminar about automotive safety, during which I had one of those very rare epiphany moments. I thought "Aha! I know how to address the question now".

The comparison between where you were in '64 and where you were in '74 was the wrong

comparison. The right question to ask was, where would you have been in the 70s rather than where you are now. So I went back and looked at smoking patterns before '64 and basically did a time-series regression analysis projecting out where smoking would have been in 1974, including as factors some of the major anti-smoking events. It turned out that by that time, smoking would have been about 25% higher than it was had it not been for the antismoking campaign.

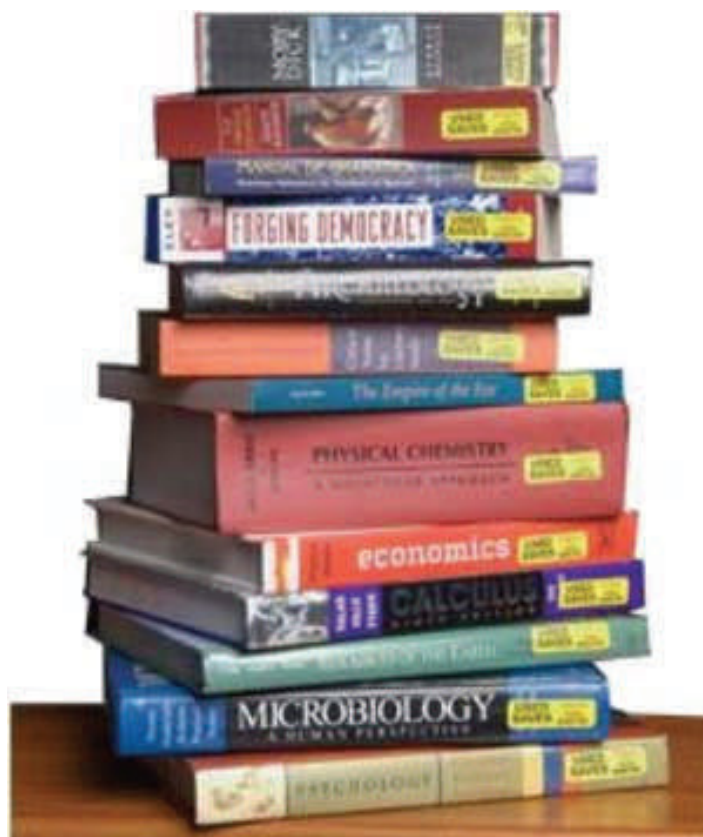
I published that in '77 and instantly got all kinds of reactions. Before I had gotten good reactions to my papers, but entirely from other academics. Here all of a sudden I received letters from the executive VP of the Tobacco Institute, congratulating me on discovering with publicly available data what they had known with their proprietary data for years. And then I get a phone call from the Secretary of Health and Human Services asking me to interview to direct the very first Office on Smoking and Health. I'm 30 years old or so, and all of a sudden all these wild things are happening. That made smoking seem a little more interesting than medical technology to me.

I thought when I started looking at medical technology that it was pretty hot stuff back then, but I got real bored with what I was doing with it. Then I thought, well here's this little piece of vegetable matter rolled up in a piece of paper with a little filter tip on the end of it, and it has really been endlessly fascinating. It's got the technology of cigarette development, the sociology of smoking, the economics, politics, the biology...you name it, they're all there, they're all put together, and it's just endlessly fascinating, and I haven't gotten bored with it after 30 years.

What has your current research been, and have there been any major changes in the direction of your research?

Since becoming the Dean I haven't had a whole lot of time for research unfortunately, but I am still continuing to do some of it. I have one colleague, who I'm working very closely with, David Mendez, on a project funded by the Bloomberg Project. We have to provide projections so that the

World Health Organization can come up with goals for target smoking levels around the world over the next 10, 15, 20 years. We got selected for this because many years ago we did some forecasting where we figured out what the rate of smoking would be if nothing changed from the initiation and cessation rates going on at the time, and the answer was that prevalence would drop gradually as more people quit than started, but then eventually prevalence would level off. We did this years ago, shortly after the Public Health Service had come



out with its Healthy People Objectives for the Nation which it does every 10 years. The objective for the nation they had in 2010, which they had set in the late '90s, was to get smoking prevalence down to 12% (from about 30% in those days). Using our model, we determined the only way that was going to happen is if we practically quadrupled the rate of quitting and got initiation down by $\frac{3}{4}$ or something, so we said this was never going to happen.

Of course we were the bad guys, but our argument was, the 12% target was not only unrealistic for 2010, it's unrealistic for 2020! And they've got themselves between a rock and hard place now

figuring out their goal for 2020, because the realistic one that's still a challenge would be no lower than 14%, but to say that would be 2 points higher than the goal they made for the previous decade. Anyway as a result of the attention from that work, the Bloomberg folks asked us to do something of that nature at the global level, and it's much much tougher. The data for smoking rates in developing countries are very very poor, so we have to be creative in how we're going about it.



Another issue I've been working for almost 15 years is tobacco harm reduction, like the e-cigarette, one of dozens of novel products. The whole question is, what do you do with these things? Do you regulate them? How do you study them to figure out whether they're really better for health or not? It's far more complicated than just evaluating the individual product and how it is used by the individual. You then have to ask yourself, how is it going to affect the public as a whole? Will it get kids to start using tobacco who will then become smokers who might not have? Will it get people who have quit smoking to go back to regular cigarettes? It's a very complicated set of issues but that's what I have been focusing most of my time on in the last 15 years or so, and it's the toughest problem in tobacco policy that I've run up against.

The issue of healthcare reform has been on the minds of Americans lately. How does public health play into healthcare reform?

First of all, nearly everyone in public health

would say we ought to have some kind of system that guarantees that every American is covered by some form of health insurance at a bare minimum. Keep in mind that the health reform we're looking at now is not going to do that – it's going to leave a large number of people without insurance. The second thing is that a vast majority of people in public health would argue that we should have a single payer system. We're spending a large percentage of our health care expenditures on the administration of the whole system. My wife runs Children's and Women's Hospitals here, and they have literally hundreds of different insurance plans they have to deal with. Think about trying to figure that out. I don't know how many people they have working on just getting paid, but there's a huge waste there. So what is the role of public health in health reform? President Obama has given more attention to the role of public health in health reform than any of his predecessors. There's a lot of discussion now on getting people to behave in ways that will make themselves healthier rather than having to rely on a healthcare system after they are already sick or injured. One of the bills includes a ten billion dollar public health fund. The level of interest in public health that this administration has been showing hasn't been seen for years.



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Italian Center-Right Parties and Immigration: A Political Patronage Approach

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Summary of paper prepared for the University of Michigan's Undergraduate Research Journal

OVERVIEW AND THE CENTER-RIGHT'S IMMIGRATION RHETORIC-POLICY DIVIDE

The immigration issue has caustic in the Italian arena and is one of the most salient issues for Italian voters. The Italian electorate is more xenophobic than most of its European counterparts. A 2003 German Marshall Fund survey found that 78% of Italians surveyed believed immigrants constituted an 'extremely important' or 'important' threat to Europe in the near future. A survey¹ conducted by the *International Herald Tribune* in May of 2007 found that 55% of Italians believe there are too many *legal* immigrants in Italy. This statistic is significantly higher compared with bordering nations. When asked how they believe the illegal immigrant situation should be remedied, a stunning 60% of Italians believe all illegal immigrants should be expelled. This percentage is the highest of any European nation surveyed.

Italian center-right parties are especially

¹ The data was gathered using the statistical polling database, Polling the Nations.

impacted by the immigration issue; center-right parties are seen as the most obvious advocates for more repressive immigration policies. There are four major parties of interest to this analysis, all of which made up Berlusconi's center-right coalition from 2001 to 2006. First was Berlusconi's own party, *Forza Italia* (FI), generally representative of business interests. Second was Gianfranco Fini's post-fascist *Alleanza Nazionale* (AN) party. Third was the regionalist and populist *Lega Nord* (LN) headed by Umberto Bossi. The last relevant actor includes the remnants of the once powerful Christian democrats, the *Centro Cristiano Democratico-Cristiani Democratici Uniti* (Ccd-Cdu) which later formed the *Unione dei Democratici Cristiani* (UDC) (Geddes 2008).

These parties adopted xenophobic rhetoric mirroring the anti-immigrant sentiments of their respective bases. For example, in the 2008 general elections, the center-right's xenophobic mantra manifested itself symbolically; single visible minority received the backing of the largest center-right party, Berlusconi's *Popolo della Libertà* (PDL)². In another incident, the right-wing regionalist LN party joined with protesters opposing the granting of land for the construction of a mosque near Milan by threatening to cover the area with pig manure (Saint-Blancat and Schmidt di Friedberg 2005). What is more noteworthy, however, is that such rhetoric seldom was transformed into policy. Consider the 2001 Bossi-Fini Act, a significant immigration reform bill pioneered by LN leader Umberto Bossi and FI leader Gianfranco Fini. The Act exemplifies that although far-right parties in center-right coalitions, such as the LN, are often the

² Statistic gathered from the Ministero dell'Interno (Ministry of the Interior) website: http://politiche.interno.it/ind_poli.htm

catalysts of immigration reform, the resulting policies have largely maintained a social-welfare net for immigrants (Zincone 2006a). The Act resulted in the greatest case of regularization in modern Italian history, granting amnesty to some 634,728 illegal immigrants (Zincone 2006a). This case of right-wing parties endorsing repressive party platforms yet adopting centrist immigration and visible minority policies is referred to in this paper as a rhetoric-policy divide.

A few relevant examples of the rhetoric-policy divide are henceforth provided. After the passage of the Bossi-Fini Act, The LN's Maroni, acting as Welfare Minister, approved generous immigration rates, including 159,000 in 2005, the highest level in Italian history (Zincone 2006a). The largest growth in legal immigrant population in Italy occurred between 2001 and 2006, when some 1.37 million immigrants entered Italy (Geddes 2008). Maroni even proposed abolishing the quota system altogether in 2003, although the proposal proved too solidarist even for moderates in the government, and subsequently never materialized into policy (Zincone 2006a). Another striking case of a moderate policy is that of AN leader Gianfranco Fini, who in October of 2003 as Deputy Prime Minister introduced a bill granting immigrants the right to vote in local elections, reversing his prior opposition to such a practice (Zincone 2006a).

In this paper, I forward a theoretical framework linking the center-right's immigration rhetoric-policy divide with the Italian culture of political patronage, two topics which, to the author's knowledge, have never been analyzed in tandem. I extend the selectorate theory to show how Italian center-right politicians use political patronage to compensate for moderate immigration policy adoption. I then argue that xenophobic voters face a collective action problem when voting for their center-right representative. Finally, I use multidimensional spatial representations to model the theoretical arguments developed in the paper and draw additional inferences. This political patronage approach is preferable over alternative theories because it can be generalized to explain other issue-driven rhetoric-policy divides in Italian politics.

THE IMPETUS FOR CENTER-RIGHT PARTY MODERATION

The academic literature provides several possible motives for center-right party moderation. One prevalent argument offered in the political literature deals with interest group politics; the preferences of centrist interest groups, specifically solidarist Catholics and functionalist employers, are responsible for the moderate policies adopted by center-right coalitions. Caponio (2005) argues that pro-immigrant groups could rely on Catholic organizations for lobbying support. Zincone (2006a) suggests that the Catholic bloc is reinforced by the support of functionalist employers' organizations who favor the inflow of cheap labor. Because Catholics and businesses make up a significant section of the center-right base, the effect of their preferences on center-right immigration policy cannot be discounted.

A secondary explanation for moderate center-right immigration policy adoption is that center-right political actors are more informed with respect to the immigration issue. There is little evidence supporting a direct correlation between heightened immigration levels and rising crime rates or negative economic consequences. Data from the OECD and *Istat* show that although immigration rates have steadily increased in the past decade, yearly unemployment has actually decreased with time. Further, yearly real GDP growth rate has been relatively constant in spite of rising immigration levels. Finally, Bianchi et al. (2008:12) find that "total criminal offenses as well as most types of crime are not related to the size of immigrant population once endogeneity is taken into account." This information is likely to be readily available to policymakers, whereas the public is more likely to not be aware of such statistics.

A further possible explanation for why the center-right may wish to adopt moderate immigration policies is that center-right parties are responding to the increased diversification of Italian society. According to the OECD, the number of immigrants in Italy has risen from 1.5 million in 1995 to 5 million in 2006. Center-right parties aware of the dynamic nature of their electoral base may

therefore be seen as using policy as an appeal to the future electorate and using xenophobic rhetoric as an appeal to the present electorate.

Clearly, there exist a myriad of possible motives for center-right immigration policy moderation. Therefore, treat this condition as a given; Italian center-right parties want to achieve moderate center-right policies. However, academic analyses of how center-right actors are able to achieve this moderation are largely unsatisfactory. For this reason, I shift the focus from *why* center-right parties wish to achieve moderate immigration policies to *how* they are able to do so. I argue that the comparatively high levels of political patronage in Italy grant political actors a mechanism to reverse their stated positions on immigration issues and adopt moderate policies.

POLITICAL PATRONAGE IN ITALY AND THE SELECTORATE THEORY APPLICATION

Ever since the 1948 creation of a parliamentary democratic republic, Italian politics has been plagued by unusually high levels of corruption and political patronage (Golden 2000, Golden 2003, Golden and Picci 2005). In fact, in 2000 Italy ranked as the most corrupt 'wealthy democracy', and had levels of corruption more reminiscent of underdeveloped countries like Uruguay than developed European states like Germany (Golden and Picci 2005). Rizzi and Stella (2007) estimate that up to 700,000 Italians are supported or otherwise make their living off of the Italian political patronage system. Although some decrease in political patronage occurred after a significant anti-corruption campaign in the early 1990s named *Mani Pulite* (Clean Hands), the culture of political patronage clearly remains in present-day Italy (De Monte and Papagni 2007).

The system of political patronage can be formalized through the selectorate theory developed by Bueno de Mesquita et al. (1999), Bueno de Mesquita et al. (2003), and Bueno de Mesquita et al. (2008). The selectorate theory assumes that in a state with N citizens, a subset of those citizens, S , known as the selectorate, actually plays a role in determining whether or not an actor remains in

office. A further subset of the selectorate, W , makes up the winning coalition, or the number of supporters needed for an actor to remain in power. In order to stay in office (which Bueno de Mesquita et al. (1999) define as the universal motivator of all political actors), actors consider the size of their W . When faced with a large W , policymakers are likely to attempt to gain the group's support through the diffusion of public goods (Evans et al. (1993)), (Bueno de Mesquita et al. (2008)). The non-excludability of the public good means that a member of an actor's W can leave the coalition and still reap the benefits of the public good (Bueno de Mesquita et al. (2008)). This means that it is relatively easy for people to leave a W if they are not pleased with the actor. Conversely, a policymaker facing a smaller W will shift focus to key individual players, and the distribution of private goods becomes a more effective means to assemble a W (Bueno de Mesquita et al. (2008)). Because private goods are excludable from others, each individual in the W benefits more than members of the selectorate. Therefore, members of an actor's W will be less likely to defect because they will lose access to private goods, ensuring the politician's re-election bid (Bueno de Mesquita et al. (2008)).

The selectorate theory offers answers to the center-right immigration dilemma. Center-right actors can keep their electoral base relatively satiated through the distribution of private goods. Because of the high saliency of immigration issues for the voter base of the center-right, private good diffusion is likely to be more significantly used, rendering political patronage more widespread. Further, because of the prevalence of political patronage, the expected political (or legal) cost of engaging in such practices is not high (Del Monte and Papagni 2007).

THE EFFECT OF POLITICAL PATRONAGE ON VOTER BEHAVIOR

Political actors would not diffuse private goods if they did not seek to affect voter behavior and enhance their re-election bids. I argue that the political patronage system is used by political actors to cause a systematic mass deviation in the

payoffs (and therefore, the voting preferences) of the electorate.

First, voters may not be as aware of the policies endorsed by a specific politician but they are likely aware of their personal benefits incurred from private good diffusion; this creates a problem of asymmetric information. Another significant consideration that makes re-election more lucrative to voters is the knowledge of the unfeasibility of cooperation. If the voters of an individual constituency coordinate and oust their MP (Member of Parliament) but all other constituencies re-elect their MP, they no longer benefit from private good diffusion *and* the rhetoric-policy divide is relatively unaffected. This creates a collective action problem for voters; the benefit is incurred if all manage to coordinate (to oust their MPs), but each player suffers if they coordinate (oust their MP) while the rest defect (re-elect their MPs). Therefore, if people are risk-neutral (or risk averse), they have an incentive not to oust their MP.

This analysis can be represented more formally by depicting a voter's decision regarding whether to 're-elect' or 'oust' as a decision tree, as shown in Figure 1. Suppose that a voter receives a payoff $X-p$ from ousting and a payoff of kX from re-electing, where $0 < k < 1$. k in this case is a measure of the relative decrease in utility caused by the MP adopting moderate immigration policies, and p is the decrease in utility to the voter caused by asymmetric information and the knowledge of a collective action problem. In this case, if $k > 1 - (p/X)$, then $P_o < P_r$, where P_o is the payoff from ousting and P_r is the payoff from re-electing. I argue for the likelihood that, from 2001 through 2006, xenophobic voters received higher payoffs from re-electing than ousting, meaning that the reduction in payoff caused by p was greater than the reduction in payoff due to k . This ensured the continued re-election of politicians who were able to continue to adopt moderate immigration policies.

SPATIAL REPRESENTATIONS

So far, I have not provided an explicit reason why MPs would choose not to also moderate their rhetoric. The answer to this question, along with

further support of the conclusions of the political patronage approach, can be derived through spatial representations which draw loosely from the veto player framework of Tsebelis (2002).

We begin by first representing the preferences of voters and MPs on a spectrum. Estimated policy and rhetoric preferences of voters and MPs are shown in Figure 2. The ideal point of the median voter is v and the ideal point of the median center-right actor is MP. The median voter's reservation point, or the point leaving the voter indifferent between re-electing and ousting the politician, is rp . We can derive that all points which are the same distance away from v as rp are also reservation points, and this is displayed through the indifference curve which passes through rp (labeled ic). An MP facing an electorate with the preferences noted in Figure 2 can adopt any position which lies along or inside the ic , but not outside of it without being ousted from office.

Now we can turn to a comparative statics analysis to assess the effects of private good diffusion. *Ceteris paribus*, private good diffusion renders voters more accepting of positions which differ from their own. The result is that the reservation point becomes more solidarist, and the indifference curve shifts outward. This means that, after private good diffusion, the MP is able to adopt a position closer to his own ideal point while still maintaining the support of the voters. This is shown in Figure 3: before private good diffusion, the MP had to adopt position p , whereas after private good diffusion, the MP could adopt a more solidarist policy position, p' .

A question remains, however: why would center-right political actors mirror the preferences of the electorate on the rhetoric dimension? Consider Figure 4; there are three MPs represented who all have the same ideal policy stance but differing ideal rhetoric stances. MP_3 , who mirrors the preferences of the electorate, is able to adopt a position (p_3) which is more solidarist than either MP_2 or MP_1 . Even without private good diffusion, center-right MPs seeking to adopt moderate immigration policies should mirror the rhetoric of the electorate. Thus, *ceteris paribus*, mirroring the electorate's rhetoric allows the MP to adopt more solidarist policies.

Further, are there any possible rhetoric positions which the MP can adopt in order to adopt policy preferences which, on the policy dimension, lay past the voter's reservation point? Indeed, a graphical analysis does show that this is possible in multiple dimensions. Consider Figure 5. If one draws a horizontal line along the voter's policy reservation point, we can derive a region (the shaded triangle) delineating where an MP is able to adopt rhetoric positions which lie below the voter's policy rp. In essence, if (v MP) lies within the shaded triangle and the MP's ideal point lies outside the voter's indifference curve, then the MP will adopt a policy which lies below the voter's policy rp.

CONCLUSIONS

To recapitulate, a multidimensional spatial analysis supports the conclusions of the political patronage approach. Center-right political actors can adopt moderate or solidarist immigration policies while retaining the support of xenophobic center-right voters. This can be achieved in two ways; through private good diffusion, which shifts out the indifference curves of voters, and through the adoption of xenophobic rhetoric which mirrors the preferences of the electorate. This conclusion is shown in Figure 6.

Overall, I seek to provide an alternative approach, as summarized in Figure 7, to the study of immigration and center-right parties in Italy. The important contribution of the political patronage approach is in its analysis of the center-right's immigration rhetoric-policy divide in tandem with the Italian political patronage system. While political patronage and the positions which center-right politicians adopt may seem unrelated at first glance, I argue that political patronage is the primary reason why the rhetoric-policy divide can exist. Further, despite the apparent peculiarity of the Italian center-right's rhetoric-policy divide on immigration issues, I suggest that it can be described using simple game-theoretic tools. In so doing, I argue that the center-right's rhetoric-policy divide on immigration issues is not a unique aberration, but rather a predictable product of rational choice behavior and a suitable system of political patronage.

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APPENDIX

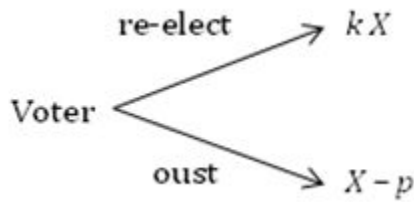


Figure 1)

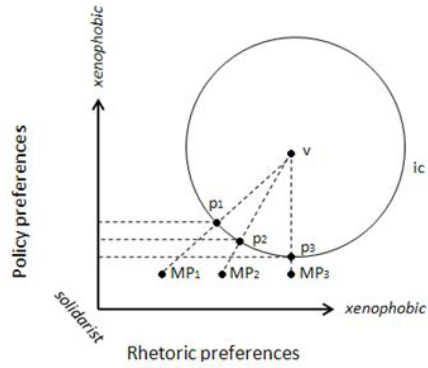


Figure 4)

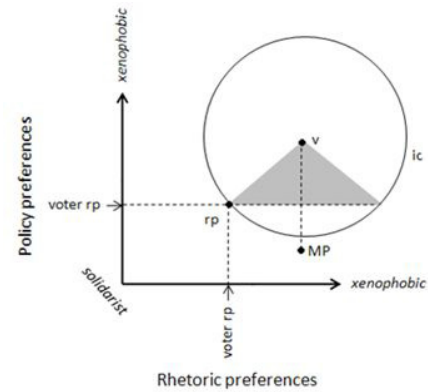


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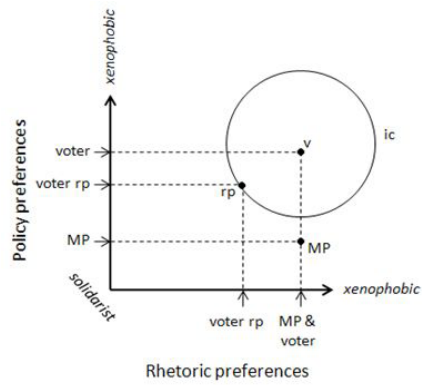


Figure 2)

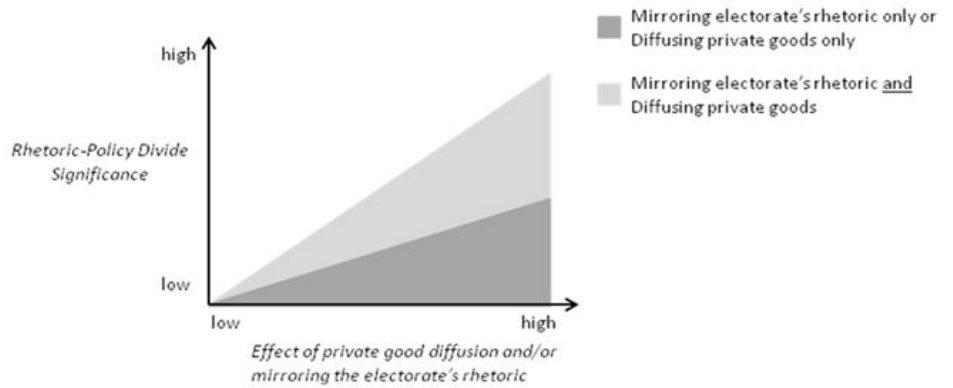


Figure 6)

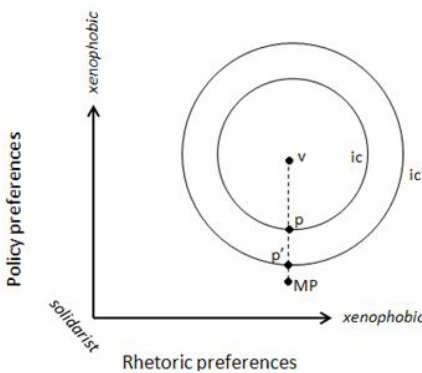


Figure 3)

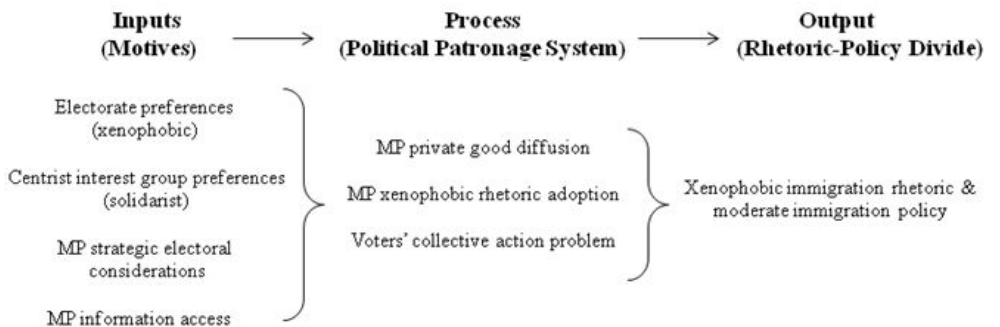


Figure 7)

Microdroplet target synthesis for kHz ultrafast lasers

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INTRODUCTION

Recent progress in the field of ultrafast laser science has allowed for many new experiments in the ultra-relativistic regime, with such potential applications as more versatile proton acceleration, which can be used for e.g. cancer therapy, and fast ignition of inertial confinement nuclear fusion. However, most practical applications, such as these, in addition to high intensities, also require a high repetition rate (e.g. kHz), which provides additional difficulties for the set up of the laser and the experiment. One major problem associated with high rep-rate experiments is obtaining a suitable new target for each shot, while maintaining spatial stability. Specifically, this complicates the experiments that require the higher density solid targets. Some common solid targets used include a rotating wheel that is scanned by the laser focus similar to a compact disc⁴, or a metallic tape of no less than 1 μm thickness. However, it is easy to see the limitations on the types of targets that can be used with such systems.

BENEFITS OF 1 μm SPHERICAL TARGET

In this work we developed a method for producing a spatially stable heavy water droplet approximately the size of the focal spot ($\sim 1 \mu\text{m}$ radius). Since there is no substrate for the target, any conductive heat dissipation is blocked, whereas in conventional targets heat has been shown to spread to more than 100 times the area of the original interaction region in ~ 500 fs after the laser shot¹, which is a typical timescale considered for such experiments as fusion or for laser-cluster interactions^{2,3,4}. Further, the absence of a substrate also allows for less dispersion of charged particles and x-rays in the target, thus yielding better proton, ion and x-ray beams⁴, which can then be used to study the dynamics of the inner-target interaction³. Additionally, the target obtained is small enough to allow the exploration of spatially deterministic near cluster dynamics (the droplet is only about order larger linearly than the largest clusters typically used), which has not been done before². Finally, the droplet produced in this work is about four times more stable than most typical solid targets used with kHz lasers, which has obvious benefits for the efficiency and accuracy of experiments.

EXPERIMENT

The experimental setup used is shown in Figure 1. Here, after the reflection from a wedge, the main laser pulse (Ti:Sapphire CPA laser with 800 nm central wavelength, 500 Hz repetition rate, and ~ 30 fs pulse duration) entered the vacuum chamber, where it was focused by an $\sim f/2.5$ paraboloid (to a $2.4 \pm 0.1 \mu\text{m}$ FWHM focus with pointing instability of $\pm 0.2 \mu\text{m}$) onto the 5 or 30 μm diameter stream (ejected from a pulled fused silica capillary tip, with a backing pressure of ~ 5 MPa (exact pressure proved to be unimportant) provided by a

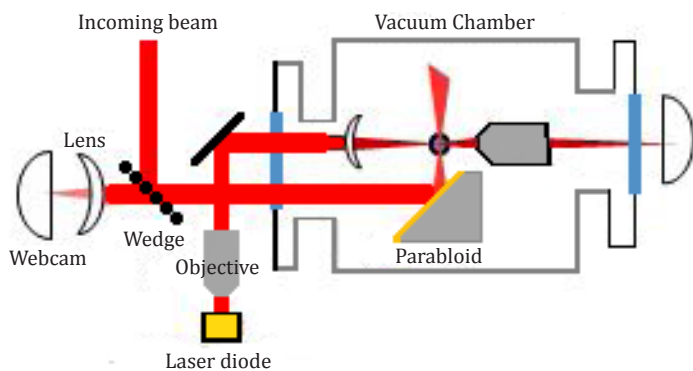


Fig 1) Experimental Setup

compressed gas), thus introducing a tiny perturbation. To ensure that the stream was centered in focus, the web-camera on the left was imaged at infinity by its corresponding lens, so that the retroreflection of the laser from the stream would focus onto the camera. Alternatively, with the $5\ \mu\text{m}$ stream it was sometimes easier to simply maximize the perturbation introduced by the laser, rather than the retro-reflection. Note that the webcam-style digital camera with a pixel size of $4.13 \pm 0.15\ \mu\text{m}$ met all the resolution requirements of this work.

For the purpose of imaging the interaction, a laser diode (5 mW, driven at 2.3 V with $\lambda=670\ \text{nm}$, pulsed with 100 ns duration) triggered from the laser and with variable delay was focused at the interaction zone to provide illumination, which was then imaged by an objective onto the second camera (see Fig. 2). This allowed the observation of the temporal development of the perturbation or the micro-explosion introduced into the stream by the laser. At various delays and intensities, such perturbations evolved into structures such as those shown in Figure 2. Note that since the diode was pulsed at 500 Hz, while the camera only took 30 frames per second, each of these images is actually the integration ~ 17 distinct exposures, and thus also provides an approximation for the stability of the feature.

RESULTS

The photograph in Fig. 2(a) displays perhaps the most promising result – a sideways droplet that was shaped by surface tension 750 ns after the laser shot out of the jet ejected from the stream by the initial explosion. The smallest stable diam-

eter measured for this droplet was $2.1 \pm 0.3\ \mu\text{m}$ with droplet stability of $\pm 0.3\ \mu\text{m}$, while its typical size varied between 2 and $3\ \mu\text{m}$ between experiments ($I \approx 3 \times 10^{14}\ \text{W}/\text{cm}^2$, stream $v = 29 \pm 2\ \text{m}/\text{s}$, droplet perp. $v = 5.5 \pm 0.3\ \text{m}/\text{s}$). In photograph (b), an inline satellite is shown which forms 6.35 μs after the laser shot, and is the result of a long-term development of a minor instability introduced to the stream – note the intensity here is 3 times lower than for image (a) – $I \approx 1 \times 10^{14}\ \text{W}/\text{cm}^2$ (satellite diameter: $3.3 \pm 0.3\ \mu\text{m}$, stability: $\pm 1.0\ \mu\text{m}$). The next two images (c and d) show potential one and two dimensional targets that could be used to match the need of a specific experiment. Image (c) shows a necking that occurs just before the stream break up – at a delay of 3.15 μs after the laser, and with even lower intensity of $I \approx 5 \times 10^{13}\ \text{W}/\text{cm}^2$. Note that this necking is extremely thin and stable, with a diameter of $1.3 \pm (\leq 0.3)\ \mu\text{m}$ and stability of $\pm (\leq 0.3)\ \mu\text{m}$ (these values are limited from below by the resolution of the imaging system). Finally, image (d) shows a window which is formed at just 100 ns after the laser shot by exploding the center of a $30\ \mu\text{m}$ stream with intensity on the order of $10^{15}\ \text{W}/\text{cm}^2$ (exact value proved to be unimportant) (thickness: $1.6 \pm 0.3\ \mu\text{m}$, stability: $\pm 0.9\ \mu\text{m}$). Thus, as can be seen from comparing these four scenarios, the observed features change drastically with time delay and the laser intensity.

DISCUSSION

Several points still remain that require consideration. Firstly, all the above experiments have been carried out both in air and in low vacuum ($5.8 \pm 0.5\ \text{mbar}$), yielding similar dynamics in both cases (except better stability was observed in vacuum), which is to be expected, as the viscosity

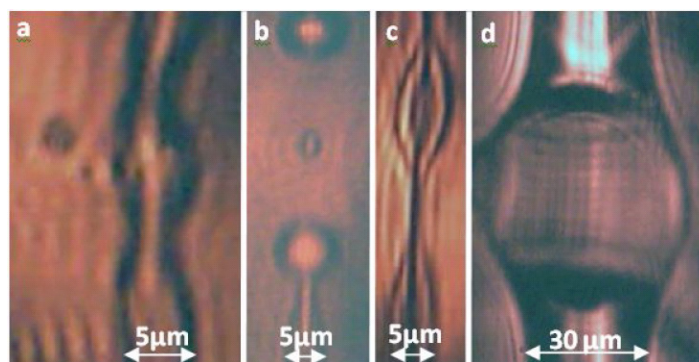


Fig 2) Various Features of $1\ \mu\text{m}$ order

of air is nearly constant over this pressure range. Nonetheless, at higher vacuum levels, we can still expect the dynamics to be similar, at least at the early delays (images a and d), where the explosion shock waves and surface tension have a much stronger effect than air drag.

Second, two common issues related to water in vacuum are evaporation and freezing. When working with higher vacuum, the stream freezes upon hitting the chamber wall, forming an ice pillar that even with a 5 μm horizontal stream can reach a length of over 20 cm in a matter of seconds, potentially freezing over the nozzle. However, this problem has many possible obvious solutions. The problem with evaporation arises when the “atmosphere” of vapor around the stream is dense enough so that its breakdown disperses the main interaction pulse used for experiments. However, from simple kinetic theory considerations at water-vapor equilibrium, it can be shown that the upper limit on the density of vapor just above the surface of a 5 μm stream is $\sim 10^{-5} \text{ g/cm}^3$ – five orders less than the density of the stream itself, and thus this does not cause problems.

Finally, one might consider that instead of using the method presented in this paper, it could be possible to simply laser-machine a 1 μm hole in the side of a capillary and explode the water inside in order to push droplets out. Although such method has potential benefits, it was attempted and proved to be infeasible, as the static water inside the capillary began to boil far below the required intensity, resulting in instabilities, in addition to multiple other technical complications.

PERSPECTIVES

One of the main limitations on the method presented in this paper was the imaging technique used. The use of coherent illumination with wavelength close to 1 μm made it impossible to reliably image features much less than 1 μm in size. Specifically, in Figure 2, image (a), we can observe a small droplet-like feature of $0.8 \pm 0.1 \mu\text{m}$ diameter to the lower right of the droplet; however, there is no way to differentiate this from an interference artifact, and thus no conclusions can be made. Further,

considering the mechanisms of droplet formation that were observed, the possibility of producing features significantly smaller than the size of the original perturbation seems unlikely. Thus, to investigate the possibility of obtaining targets $\leq 1 \mu\text{m}$ in diameter with a similar method, it is necessary to use either shorter wavelength or incoherent light for imaging, and to achieve tighter focusing of the perturbing laser.

CONCLUSION

As a result of this work, we were able to experimentally show the possibility of producing spatially stable ($\pm 0.3 \mu\text{m}$) deuterated water droplets of $2.1 \pm 0.3 \mu\text{m}$ diameter, as well as other one and two dimensional structures of near 1 μm size along the smaller dimensions for use as a new generation of targets for high rep-rate lasers.

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Ancient Maya Beekeeping

(ca. 1000-1520 CE)

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ABSTRACT

This research integrates sixteenth century and later written descriptions of the people of the Maya lowlands with archaeological evidence from Postclassic (1000-1520 CE) sites in the Yucatan to examine the significance of beekeeping in the ancient Mayan world. These various lines of evidence illustrate the numerous connections between the production of honey, religious practices, beliefs, and trade between Mayan centers. The model of Postclassic Maya apiaries developed here may be used both to predict the nature and location of beekeeping for future archaeological research and to evaluate new, or otherwise unexamined, data from archaeological sites.

METHODS

To learn about Mayan beekeeping practices, I examined Spanish accounts, ethnographic accounts, and contemporary information that included information on the appropriate habitat for apiculture in the Yucatan Peninsula. By comparing the Spaniards' accounts of 16th century beekeeping with more recent accounts, I was able to conclude

which aspects of beekeeping tradition remained unchanged or were only slightly affected during the last five hundred years. To examine more ancient practices, I focused on the material traces of apiaries that would preserve at archaeological sites. Historically, Mayan beekeepers use stone plugs, called panucho plugs, to seal the hives.

By comparing these diverse sources of information, I drafted a model for such practices and then evaluated the efficacy of this model by using archaeological site reports that exist for Yucatán and Cozumel. Included in this model are characteristics of beekeeping, such as where apiaries were kept, the labor costs of each apiary, and production of beekeeping goods themselves. I will focus on five main topics: location of apiaries, size of apiaries, yields of beehives, labor requirements, and development and sustainability.

HISTORICAL SOURCES

An important source of information is Bishop Diego de Landa's account of the Yucatec Maya of the sixteenth century in his book *Relación de las cosas de Yucatán*. In this account Landa describes the beekeeping practices of both domesticated *Melipona beecheii* (the most-used stingless honey bee) as well as the practices of hunting and collecting honey from wild bees in the forests. Some groups that Landa observed tended apiaries, drawing honey and wax from the hives in ways that preserved the bee colonies and established a symbiotic relationship. The bees and their honey were considered sacred and valuable. Another important historical source is Diaz and Oviedo descriptions of beekeeping on Cozumel during the Spaniards' first few visits to this island. These accounts plus the ethnohistoric information were key to developing

a model of size and location of the average ancient Maya apiary from the Postclassic period.

CONTEMPORARY AND ETHNOGRAPHIC STUDIES

Because Maya beekeeping and the stingless bees are nearly extinct, G. R Villanueva (2005) and others have recorded a vast amount of statistical and behavioral data on beekeeping practices in eastern Yucatán. The information they gathered is of great, not only for ecological and apicultural conservationists, but also provides insights into past practices. For instance, the type of log hives that Villanueva (2005) observed in use, along with stone panucho plugs sealed with mud, match the descriptions and archaeological evidence of hives from Postclassic sources, such as the account by Landa (1566) and the site reports of Postclassic sites in Yucatán and on the island of Cozumel (Crane 1999). The type and size of log hives, the number of colonies managed by a father within a nuclear family, and the size and construction of the shed or *palapa* in which the colonies are protected seem largely unchanged (Figure 1a & b). The real lesson from Villanueva's research is not merely the data on yields per hive or size of hive clusters but the continuity of a practice that has endured for at least five hundred years despite intense outside pressures working against it. It also shows a Maya perspective on stingless beekeeping that is yet to be discussed in scholarly accounts.

RELIGIOUS TRADITIONS

Alcohol, and the honey which is used in fermentation to produce alcoholic drinks, are both very important in Maya feasting rituals. Diego de Landa described the numerous feasts among the 16th century Maya, including political, agricultural, and calendrical events, most of which involved the consumption of balché (an alcoholic beverage made from fermenting the bark of a tree) (Landa 1566 in Tozzer 1941).

These bee-products were not just used in important ritual activity - Bee-Gods were worshipped directly as well. Sharer (1994:552) discusses a particular ritual that celebrated Maya bee-

keepers who prepared during the month of Zotz for the feasting ritual held the following month, Tzec.

“Incense was burned and pictures were painted on the incense boards, using honey as paint. The object of the feast was to increase the yield of honey, and the owners of hives contributed an abundance of it, from which was a wine brewed with the bark of the balché tree; heavy drinking of this beverage concluded the ceremony.”

Diana Cohn (2005:656-657), currently working in a partnership with El Colegio de la Frontera Sur (ECOSUR) on the program “The Bee Works,” sheds further light on the immense religious importance of *Melipona beecheii* to the ancient Maya. She writes:

“Native “Xunan Kab” were so revered during the times of the Classic Mayan period that they were depicted as gods. The Mayans prayed to the stingless bees and in the temple of the Descending or Diving God at the coastal ruins of Tulum and interior Coba, they carved stone relief images – with a depiction of Ah Mucen Kab, their god of beekeepers, bees, and honey.”

Objects have been found that link beekeeping to Maya religion. One prime example of this is a mother-of-pearl pendant depicting Yax Balam (Xbalanque) with the body of a bee. According to Kerr (2003:6), Xbalanque is depicted as many things, but most interestingly as a beekeeper and bee emulator. He explains that Mok Chi', the image that Xbalanque takes, can be translated by reading the glyphs as follows: “that MOL (T581) can mean ‘to gather’ and MANIK (T671) can mean ‘sweet’. The written name thus means to ‘gather sweet’ and that is exactly what Mok Chi’ does” (Kerr 2003:6).

GEOGRAPHIC LOCATION

Xunan-kab, the Mayan term for *Melipona beecheii*, can be found ranging from present-day Mexico to Costa Rica. Transition: although wide range – hives found on in certain environments. For

example, the Spaniards' accounts do not describe any apiaries near the ocean. This is corroborated by contemporary ethnographic accounts in which coastal areas are avoided; the apiaries are protected under *palapas* (palm-roofed shelters that cover the racks of hives) to shield them from hurricanes and harsh weather coming from the sea (Villanueva et al. 2005:39). The Grijalva expedition in 1518 recorded apiaries on the inland side of the villages. The inland side of the archaeological site of Cozumel has panucho plugs but the ocean side does not.

As both the reports of the Spaniards during the times of first contact and the ethnographic contemporary reports show that honey was almost entirely used for balché production, it follows that areas which have the most panucho plugs were most likely the areas that produced the most balché. It would also follow that these areas would then export some balché to areas where apiaries were not as viable or at least not well established.

APIARY SIZE

The Spanish accounts from 500 years ago describe apiaries with a greater number of hives than have been recorded in more recent times. While some of this variation is likely attributable to exaggeration by the Spaniards, not all of the evidence should be dismissed as an overstatement. The Spaniards, primarily Diaz and Oviedo (Crane 1999:292), describe, "apiaries with 1000-2000 hives in trunks of trees, well made, with their openings and entrances... the extremes plugged with a stone for each end." The ethnographic accounts, mainly the study of hives in the present-day Zona Maya in Yucatán by Villanueva et al. (2005:36) show that families in the mid twentieth century often had 50 to 200 hives. Due to present trends, economic difficulties, and the introduction of other species, the largest known hive clusters in apiaries today are only 12. I think it is likely that Postclassic period apiaries contained between 200 and 2,000 hives. This may seem like a vast range, but it indicates two rather important points: (1) this was not a small family industry consisting of little groups of four to ten hives, and (2) honey was not mass produced on a large scale, at least within a small area.

Likely, the number of hives did not exceed the low thousands, due to the number of available pollen sources within the range of the bees. Porter-Bolland agrees with other scholars, in that *Melipona beecheii* have a maximum territorial range of 300 square km (2001:305). This limit would be further enforced by the bees' practice of culling pollen from secondary-growth plants as the Maya started to cut down the forests of Yucatán (Villanueva et al. 2005:35). This deforestation not only acted to limit the amount of pollen available to honeybees, but also made the species considerably more dependent on domestication due to the destruction of their natural habitat. In the wild, *Melipona beecheii* chose to live in logs that are typically more than 30 cm in diameter. As these trees would have been, and continue to be, the ones most often targeted by loggers, they would have become increasingly scarce (36). Thus the amount of honey and wax being produced was enough, in conjuncture with other construction efforts, that the Maya's pattern of resource use was not sustainable, as the plugs found have shorter diameters in the coastal and deforested areas showing a reduction in production and availability of resources for their key production goods.

HONEY AND WAX YIELDS

One log colony of *Melipona beecheii* can produce an average of 2 kg of honey per year (Aguilar 2001:44-49). Ratnieks (2001:1) is slightly more conservative in estimating yields of honey, stating, "...each hive makes 0.5-1.0 kg of honey per year." Wallace (1978:19), in personal communication with Norbert Kauffeld, confirmed that, "it is probable that the smaller wooden hives used in Pre-Columbian Yucatán would have produced one-half to two cups of honey [each]."

It seems that after initial contact with the Spaniards, the Maya ramped up production of honey and wax in order to pay Spanish tribute demands. Surviving tribute lists from 1549 show that 163 Maya villages paid the Spaniards in wax and 157 villages paid them in honey (Crane 1999:293). The total for the year amounted to 3 metric tons of honey and 281 metric tons of wax (1999:293),

which Calkins (1974) determined was approximately half a kilogram per inhabitant per year.

In times of necessity, hives may be completely robbed of their honey and wax to dramatically increase yields, but this was not a long-term strategy as it would have undermined the sustainability of the colonies. In contemporary groups, hives are only robbed when their beekeeper has essentially given up on the colony and wishes to reap the last rewards before moving on to either a different species of honeybee or to an entirely different occupation (Villanueva et al. 2005:39).

Harvesting time for honey can vary depending on the scale of the apiary and labor involved. At most, it can be harvested, albeit in smaller yields, up to every other month (Villanueva et al. 2005:19). Alternatively, some groups only harvest twice per year with larger, more labor-intensive yields. Porter-Bolland (2001:309) did extensive research on flowering plant species that *Melipona beecheii* pollinate and compared yields of colonies to both rainfall and flowering species. In this way, honey and wax yields can be generalized by the seasons due to bee's need of pollen to produce these goods. Based upon Bolland's plant-flowing information, the best times for honey harvests were between February and March, and then again between May and June. If the beekeepers harvested after June, it would likely have been in smaller amounts, or else they would risk taking the necessary stores of the bees during the July thru December period when the fewest species are flowering. This is further demonstrated in Porter-Bolland's other data which compare the four stages of *Melipona beecheii* hive cycles to the months of the year, which show a decrease in activity in July thru December that matches much of the flowing cycles in the region. Additionally, it is during this time of low blooming that most rains occur, which make it much harder for *Melipona beecheii* to survive. This correlates well with the family *Lonchocarpus* (of which the balché tree is a member), which Porter-Bolland (2001:314) shows as blooming during March and April.

LABOR REQUIREMENTS

For people keeping bees, the primary labor

requirements are protection and custodial duties. One of the foremost duties would be to ensure the safety of the hive, both from animal predators as well as the weather. Landa refers to such an animal threat, stating that the "animal which they call camhol ... eat nothing but honey." (Landa in Tozzer 1941:203). Because hives were located away from heavily populated residential areas, these animals could completely destroy an apiary if they were not properly protected. Wallace (1978:40) echoes these sentiments, noting that, "It would not take much of a wall to keep an armadillo from raiding the hives, but the coati-like Tayra and the raccoon would be a different story." Protecting the hive colony is often accomplished through the creation of a protective shed (*palapa*) for the hives. Within the *palapa*, the hives are often stacked on large "A" framed wooden racks, one on top of another. Archaeological evidence, especially on Cozumel, suggests that similar structures were once made from stone rubble and surrounded the hives in a ring or approximate rectangle (Wallace 1978).

It is unclear whether a separate group would have been responsible for the storage and protection of the honey once it was harvested; if the actual beekeepers did not perform these tasks, then these others would at least have worked with the beekeepers during the harvesting process. Wallace (1978:20) notes that the most popular and effective method of preserving recently harvested honey is to boil it, creating a thicker honey that can be prevented from fermenting unintentionally.

To extract the honey, the panucho (or plug) was removed from the side of the hive where the honey nodules were located. A panucho fits into both lateral ends of a beehive. Archaeologically they are found in both limestone and coral varieties, but today they are primarily made out of wood. These plugs would be used to keep the hive closed and would only be removed when the beekeeper needed to harvest honey or wax or check on the hive itself. A select number of pods were pierced and the hive was then tipped to let the honey drain out. While this honey is quite pure, present-day groups will often strain the honey as it comes out of the hive by placing a basket of woven vine stems between the collection vessel and the hive (Crane

1999:295). Partially due to the religious importance of bees, and partially due to respect and care of the colony to preserve longevity, the bees are handled extremely carefully, especially during extraction. Redfield and Villa Rojas cover this in detail (1962:50):

“Bees are handled with some circumspection; in removing the honey, care is taken not to injure or kill any of the insects. If a bee becomes honey-soaked, it is dried and freed; if one is killed, it is buried in a bit of leaf. This is because the bees are under the protection of certain deities, who watch over them and become angered if their wards are not treated properly.”

Some studies have shown that objects other than woven baskets were used for straining. Redfield and Villa Rojas found the widespread use of perforated wooden disks for straining in the northeastern Yucatán town of Chan Kom. These disks are called *chichipche* and are placed directly above the jars for honey harvesting (1962:49). These disks unfortunately would leave little archaeological evidence behind as they would have long since decomposed, and the soil in most sites is wet enough to remove most if not all of this evidence that might otherwise be preserved in particularly arid areas.

DEVELOPMENT AND SUSTAINABILITY

Initial development of an apiary generally occurs in three different ways. Firstly, *Melipona beecheii* colonies may be directly taken from their natural habitat. The log hives they naturally choose may be brought into a village and then used to propagate an apiary full of colonies, eventually domesticating the bees. The second way to develop a colony is by capturing a homeless colony of *Melipona beecheii* from the wild and then cloning it into an apiary. Vietmeyer (1991:365) describes this process as, “the simplest and cheapest way for beekeepers to acquire a colony.” Finally, a new colony can simply be cloned from an existing one, in which a currently functioning colony is divided into two smaller colonies, often with the use of intentionally

placed, or relocated, queen bees. This was the case in Chan Kom (Redfield and Villa Rojas 1962:49), where, “A man wishing to begin keeping bees secures some from the hive of a neighbor, not from the bush.” This step is most often used in already established apiaries as a means of growth and not necessarily as a step to start a new apiary.

New log hives would be made from whatever lumber was available, particularly trees with larger trunk diameters that could accommodate a colony of bees inside of them. Villa Rojas (1945:57) notes that Maya in the 1930s would use sections of trunk from the *Vitex gaumeri* tree because it was frequently hollow by nature, and not only in a state of decay as other hollowed species often were. Cohn (2005:659) confirms this in a contemporary context when speaking with apiculturists in Quintana Roo, Mexico, “The logs are mainly from the Verbenaceae family, genus *Vitex*, a tropical hardwood tree.” Crane (1999) notes that these crafted hives were often described by Spaniards as being decorated and carved by their owners but that this practice may not have been done as frequently, if done at all, in industry-focused beekeeping as opposed to the domestic use.

As for the sustainability of the colony itself, *Melipona beecheii* is a largely self-sufficient species. Provided that their basic needs of water, nectar, pollen, and shelter are met, they will likely thrive (Vietmeyer 1991). Each log hive represents one colony and each colony nurtures its own queen, which in turn produces offspring for that colony. After approximately two to three years, the queen will become too old and the colony itself will replace her by growing a new queen. This is accomplished via the production and feeding of royal jelly, a special type of honey, to a specific young larva that develops into the new queen for the colony (Vietmeyer 1991:365). This process can repeat itself over many decades, with some beekeepers in present-day Quintana Roo, Mexico reporting hives that are “over 40 years old and [each housing] more than 3,000 stingless bees” (Cohn 2005:659). Given the correct circumstances, this longevity saves beekeepers from continually needing to start new colonies unless they have resources and desire to do so.

ARCHAEOLOGICAL EVIDENCE – BUENA VISTA

The archaeological site of Buena Vista is in the southern Cozumel, approximately 1.5 to 3 km inland from the eastern Caribbean coast and in the midst of the densest vegetation and forests on the island. Freidel (1976:367) concluded that Buena Vista was a large and dispersed community of families that shared a “nucleated core” at the center of the settlement. The panucho plugs are the primary archaeological indicators of the practice of beekeeping. It is in this nucleated core area that the majority of plugs were found (Wallace 1978:32). This suggests an industry-level production of honey and honey products, as the same levels of panuchos were not found in the residential areas in the periphery of the site.

As Wallace used the SPSS tools to perform statistical analysis upon the plugs at Buena Vista (1978:10), which contained the most plugs at Buena Vista - 22 total. These panucho plugs were of both coral and limestone compositions, found in small clusters together, were unbroken, and were found in the upper layers near the surface (1978:33).

The pairings of panucho plugs demonstrate not only spatial pairings, but pairings of both length and width dimensions of the plugs. It is this evidence that demonstrates their use as hive plugs, as not only are the pairings approximately 50 cm apart, as predicted by contemporary measurements, but these pairs also exhibit the same diameters – factors that are unlikely to occur together by chance.

Also unlike other operations at Buena Vista, Operation 67 did not contain trash deposits near the panucho plugs (Wallace 1978:34). Archaeologically, this demonstrates that these plugs are not refuse or debris, but an item that was used and further demonstrates that there were special constructed areas designated for this larger-scale beekeeping practice. Additionally, and quite similar in construction and height of Features 16a and 16b at Aguada Grande, there is a rock wall on both the east and west sides of the panucho plugs. While not forming a circle like the stones observed at Aguada

Grande, the rough construction of the stones, and the approximate height of at least a meter suggests use as both a wall around the apiary as well as a potential platform or shelf for either the log hive colonies or other (probably wooden) construction that would support the log hives.

ARCHAEOLOGICAL EVIDENCE – AGUADA GRANDE

The site of Aguada Grande is located on the northeastern point of Cozumel, approximately 0.75 km inland from the Caribbean. The occupation of the site was during the Postclassic, approximately 900-1520 CE. Friedel (1976) reports 73 panucho plugs, some made of limestone, others of coral. Wallace (1978), however, counted and examined 30 plugs from the site. These plugs were found in twin stone circles, on the western, or inland, side of the site (Wallace 1978:2). The panuchos that Wallace examined were found in clusters in Trench 1/Pit 2, from Structure 16a, the more northern of the two stone circles; the dimensions of each were recorded, including their length, width, and thickness measured at maximum diameter, minimum diameter, and thickest point (Wallace 1978:10). Wallace then performed analyses on these data points for each plug, which given the sample sizes, produced statistically significant comparisons between sites and panuchos within sites (1978:10). In sum, the average plug size was smaller than those found at Buena Vista, but slightly larger than plugs found at San Gervasio. The variability in the size of the plugs corresponds with their use as hive plugs - the dimension that varies least is their diameter, and the dimension that varies most is their thickness (1978:10). This shows that those crafting these plugs were paying attention and working the stone/coral in a way to best fit inside the opening of the log hives, and were least concerned with the thickness of the actual plug, as variation in this dimension would have almost no impact on the plugs effectiveness or the hive’s production.

Panuchos are found in two different contexts on Aguada Grande, suggesting different production sites or activity areas for the beekeeping industry. Firstly, some seem to be in a central setting, likely in controlled production such as Structure 16a and

16b, which contain clusters of plugs (1978:14). The northernmost circle, 16a, is “approximately 725 cm in diameter as opposed to 625 cm for 16b” (Wallace 1978:37). The walls of the stone circles were crumbling and architecture was hard to determine. However, it was estimated that they were 1.5-2.0 m tall when standing and separated from each other. Structure 16b had an 80 cm gap on its eastern wall that may have been the entrance to the apiary (Wallace 1978:38).

The other type of deposit, classified as “housemounds” by Wallace (1978:14), include “both interior deposits (often sealed between successive floors) and midden remains adjacent to structures.” The panuchos found in housemounds are likely simply hives kept and tended by households for the use and trade of honey and wax by household members, whereas the large stone circle features, which contain clusters of up to 50 panuchos, may be large-scale or “industrial-level” honey production areas.

The full scope of the beekeeping industry is, however, unknown. Of the area that just Structure 16a occupied, only 20 percent was excavated and 50 panucho plugs were discovered (Wallace 1978:40). It is entirely unknown just what percent of the apiary those 50 plugs represented, as the archaeologists may have simply excavated the only areas with plugs, or on the other hand, could have easily excavated the area with the lowest panucho plug density. Without more areas being excavated to increase the sample sizes of the data and specifically the density of each apiary, it is hard to estimate exactly how big some of these community apiaries may have been. Likely, they were composed of 100-200 hives at the minimum, to produce enough wax and honey as the community would need for themselves, with larger apiaries being able to serve other communities and offer tribute payments to the Spaniards.

Intriguingly, there was evidence of potential religious activity in Feature 16a as well. On the west wall of the structure, a small niche (visible in Figure 8 below) was found in the rubble walls; associated with it were fragments of a bee god incense burner (Wallace 1978:41). Citing Tozzer (1941) and Schwarz (1948), Wallace (1978:41)

agrees, “... bees and honey were religiously important ... that [the niche] was serving as an insect altar.” Only one other such niche was found on the site of Aguada Grande - it was located within a field wall just west of Structure 16a.

CONCLUSIONS

This research has shown that beekeeping and honey production were important activities of Postclassic Maya society. Comparing the historical sources, the ethnographic studies, and current research to the archaeological record has resulted in a richer understanding of the complexities of production and use of beekeeping goods. The next steps for future research are below:

1. Palynology Analysis could be performed on the layers of soil most closely associated with panucho plugs found in situ. This would be very effective, as the main item that *Melipona beecheii* transport and store is pollen itself. It would not only naturally collect around hives, but would be deposited whenever honey, and to a lesser extent wax, was spilled or otherwise came into contact with the ground. Palynology would also reveal the types of pollen, potentially on a plant-specific if not genus-specific level, which could better determine instances of intentional gardening and production of toxic and psychoactive honey products.
2. Residue Analysis could be used on stone, coral, and ceramic materials believed to be associated with honey production. Stone and coral panucho plugs could be analyzed to confirm their use as hive stoppers, as they would likely produce the most consistently positive results for honey and/or pollen residues. Additionally, testing vessels used for storing raw honey, vessels used for boiling honey for preservation, and vessels or vats used for fermentation would be a greater challenge as this analysis is costly and, given the current lack of identification or association of such vessels with honey, large sample sizes would have to be tested to generate useful results.

3. Further Field Survey, suggested by Wallace, is an activity that would both be possible and fruitful, given the high rate at which panucho plugs can be found on the surface, or having been reused in ancient buildings' architecture. Unlike many other items, panucho plugs have a distinct size, shape, and composition that make them easy to identify on the surface.

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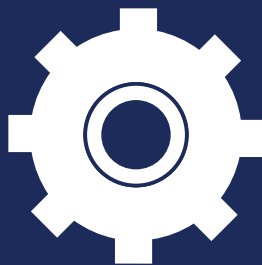
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