SURJ

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Cover photograph by Julia Turan

A Letter from the Editors

Dear Reader,

On behalf of our entire staff, it is with great pride that we bring you the tenth edition of the Stanford Undergraduate Research Journal. SURJ was established to showcase premier examples of undergraduate research from across the university. This year, we had the difficult task of choosing from a record number of submissions, demonstrating that undergraduates are taking full advantage of the opportunity to pursue in-depth study in areas of personal interest.

We are proud to bring you ten of the most outstanding papers produced at Stanford over the past year. These research projects span the full range of disciplines, from religious studies to civil engineering and from biology to political science, and are the products of introductory seminars, overseas study, and faculty-sponsored research projects.

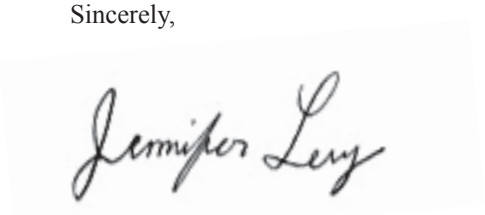
On the following pages, Adam Adler (‘12) uncovers the history of the Voting Rights Act; Anthony Alvarado (‘12) and Kristhian Morales (‘12) explore the possibilities for future Bio-Based Composites; Maggie Sachs (‘11) expounds on a new hybrid theory of religion; Caleb Kruse (‘14) searches for a solution to coral bleaching; Steven Crane (‘11) uses ants and moths as bioindicators; Harley Sugarman (‘14) compares James Bond and twentieth century propaganda, Laney Kuenzel (‘12) uses machine learning to predict BPA in infants; Siddharth Damania (‘12) explains the politics of the Patriot Act; Leslie Cachola (‘11) seeks a genetic understanding of asthma; and Charles Syms (‘11) explores an argument in transgender identity. Please join us in congratulating all of these authors on their outstanding research.

Although our journal exists primarily to showcase outstanding examples of research performed by Stanford undergraduates, we also welcome submissions from universities around the globe. This year, we are proud to bring you a fantastic research paper from the Indian Institute of Technology Delhi, in which Avikant Bhardwaj presents a machine learning classifier for automatic document summarization.

We would like to thank our entire editorial and production staff for their hard work over the past year. Without their efforts, none of what you read on the following pages would have been possible. We are very grateful to Dr. Patti Hanlon-Baker from the Hume Writing Center for her help in training our staff and helping us formulate our selection criteria. Finally, we owe a debt of gratitude to Dean Eyre and all of Undergraduate Advising and Research for their support over the past year.

Please join us in congratulating all of our authors. We hope that their hard work will continue to inspire future Stanford undergraduates in their research endeavors.

Sincerely,



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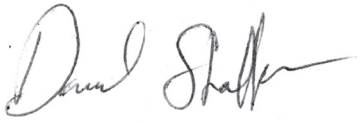
Editor-in-Chief



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The mission of the Stanford Undergraduate Research Journal is to encourage, recognize, and reward intellectual activity beyond the classroom, while providing a forum for the exchange of research and ideas. SURJ encourages students to become interested in research by displaying examples of what is studied and by offering the means of communicating knowledge between these disciplines to achieve a holistic effect.

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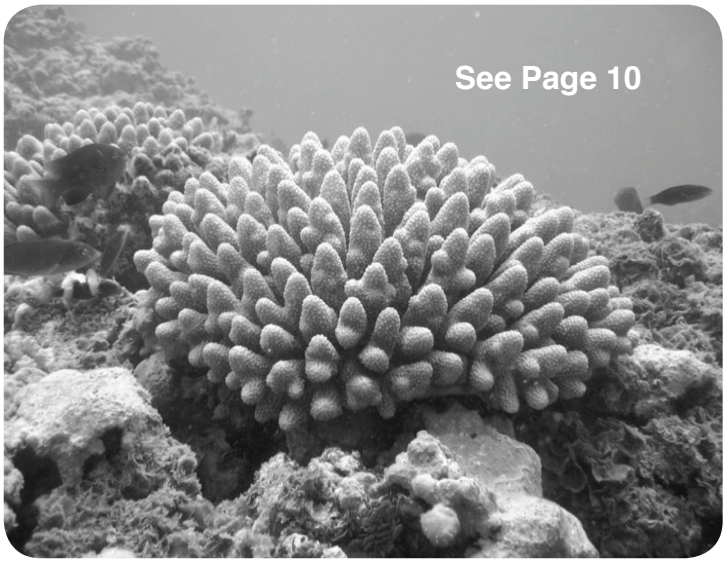

Epigenetic Changes in Foxp3 in Treg of Identical Twins Discordant for Asthma

Leslie Cachola, T. Hunter, S. Runyon, N. Rajeshuni, K. Nadeau

Asthma is characterized by airway inflammation, wheezing, coughing, and breathlessness due to dysfunctional regulatory T cells (Treg) that are normally regulated by the Foxp3 transcription factor. In this study, we investigated the role of ambient air pollution exposure in the development of asthma and increased severity of symptoms via epigenetic mechanisms. We found that identical twins had different disease outcomes, in which the asthmatic twin had lower Treg function and Foxp3 expression. Our study shows the influence of hazardous environmental exposures on health and highlights the importance of further exploration into epigenetics.

Asthma is the most common chronic childhood disease today, and children are at higher risk of asthma onset and increased asthmatic exacerbations when exposed to ambient air pollution (Nadeau *et al.*, 2010). The disease is characterized by inflammation of the airways, wheezing, coughing, and breathlessness. Normally, regulatory T cells (Treg) are responsible for maintaining airway tolerance and suppressing inflammation. Yet in asthmatic individuals, this mechanism is dysfunctional, and thus often results in hyper-responsiveness of the immune system (Lloyd *et al*, 2009). Previous studies have shown that exposure to ambient air pollution leads to changes in immunological mediators that result in asthma symptoms through a process known as "epigenetics," in which gene expression is affected without changing the genomic DNA nucleotide sequence (Bromberg *et al*, 2009). Thus, ambient air exposure poses a serious health hazard, especially for children.

Most recently, the Nadeau Lab has begun to address the role of environment in disease development in research conducted for the Fresno Asthmatic Children's Environmental Study (FACES). In Fresno, one of the most polluted cities in the U.S., a longitudinal study of children demonstrated that asthma and allergies were increased by two fold (compared to the national average) and the degree of asthma was correlated with the extent of exposure to air pollution (Tager *et al*, 2006). Yet despite its findings, it is only one of the few research studies linking environmental exposures to asthma development and severity. Though there is much evidence on downstream immune system responses to exposure, there exists a research gap on upstream processes and the immunological regulators that are responsible for health outcomes in asthma and allergies.

We plan to investigate this correlation with a specific focus on regulatory T cells (Treg) mediated by the Foxp3 protein found in a specific region of DNA known as a CpG island, because of their association with the control and treatment of asthma. Regulatory T cells (Treg) play a critical role in mediating the molecular pathways associated with asthma, which is often triggered by environmental exposure in genetically susceptible individuals. In a model for the molecular basis of asthma, environmental exposure can trigger the DNA methylation of Foxp3, resulting in the suppression of Foxp3 expression. This in turn can cause the dysfunction of Treg cells, exacerbating the symptoms of asthma at the physiological level. Of the many loci that affect Treg development and function, the Foxp3 transcription factor is known as a "master regulator" that controls the differentiation of these cells. The Foxp3 protein is often used as a marker in the identification of Tregs.

To understand the role of environment vs. genetics in disease development, we chose to study monozygotic twins discordant (MZT-D) and concordant (MZT-C) for asthma, in which discordance is defined as the twin pair having varied disease outcomes. For example, a discordant pair includes a twin with asthma and one without. Our aim is to 1) Eliminate genetic predisposition as a confounding variable and 2) Determine epigenetic markers (alterations in gene expression without changes in gene sequence) in Tregs associated with asthma and influenced by environmental exposures. Considering that identical twins have the same genome, the causes of discordance in asthma can be attributed to external social and environmental factors.

Materials and Methods

The study has over 54 fraternal and identical twins enrolled for a series of biological tests and verbal questionnaires. We enrolled any pairs of twins (up to eighty years of age) regardless of discordance or previous medical conditions. The focus is to have 25 controlled pairs (in which both twins have similar health conditions and no disease) and 25 discordant pairs (in which one twin has asthma and/or allergies and the other does not) by the end of July 2011. Each patient is first asked to sign a consent form in which our lab and clinic acknowledge confidentiality and is reimbursed with $50 for participating as well as $0.50 per mile traveled, round trip.

To confirm diagnosis of asthma, each enrolled twin participated in spirometry testing, in which forced vital capacity (FVC) was measured. Spirometry is a diagnostic tool which measures amount of air blown into the device over time— less air produced through the tube implies a degree of lung inflammation that can indicate asthma. In addition, a universal asthma control test was conducted: a series of questions addressing the severity of asthma and impact on daily life. For example: "In the past four weeks, how much of the time did your asthma keep you from getting as much done at work, school, or at home?" All results and confirmation of diagnosis would be interpreted by Dr. Kari Nadeau.

To test for zygosity (whether the twins were fraternal or identical) and allergies, blood draws of 30-100mL per patient were taken for analysis. Flow sorting techniques, Treg purification, and Sanger genomic DNA sequencing were performed on the cells derived from the blood samples. More specifically, blood plasma and leukocytes were purified from purified blood cells as well as from bronchoalveolar lavage. Zygosity as well as genetic make-up were also analyzed through buccal swab tests, in which a swab was rubbed against the inner cheeks and gums of the patient to collect cells.

Aside from biological diagnostic testing, a detailed interview of the twins

Fig. 1A

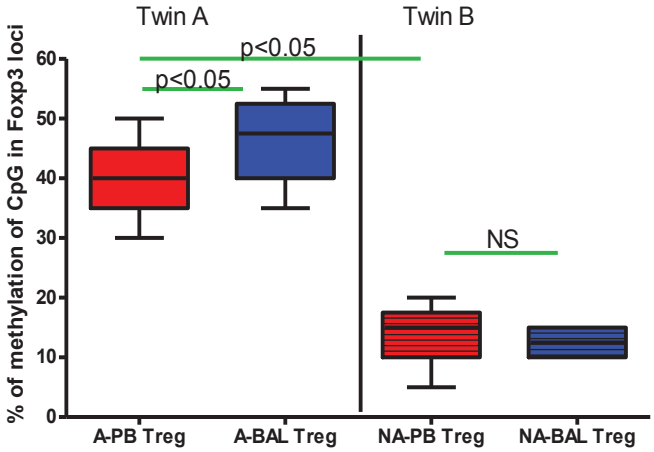

Fig. 1B

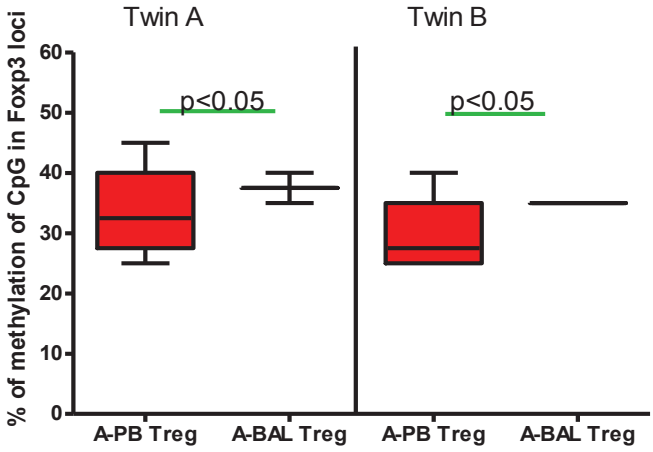

Fig. 1 Higher levels of methylation in asthmatics compared to non-asthmatics. PB Treg and BAL Treg (CD4+CD25hiCD127l) were purified via flow sorting techniques, genomic DNA sequenced as described by the Nadeau laboratory. **(A)** MZT-D twin pairs (n=8 pairs) (A vs NA) **(B)** MZT-C twin pairs (concordant in asthma, n=4 pairs). Mann Whitney Test (*significant if $p < 0.05$, NS=non significant).

was conducted to determine medical history of disease as well as various environmental exposures, such as whether parents smoked or not as well as duration of smoking history, both in years and number of packs smoked per day. Other questions included locations of all homes the patients have ever lived in for at least six months or more. Follow-up research will be done to determine ambient air pollution levels in those areas during those periods.

Results

Previous studies determined that increased methylation of the CpG region in the *Foxp3* locus was correlated with decreased function of Treg, thus resulting in increased asthma severity (Bromberg *et al*, 2009), a sign of epigenetic occurrence. In other words, *Foxp3* expression—altered by CpG island methylation— is required for the suppressive effects of Treg that prevent inflammation and asthma. Thus, it was expected that the asthmatic twin would have higher methylation levels than their non-asthmatic, identical counterpart. Healthy twins would be expected to have similar levels of methylation. We will look at pairs in which one twin has asthma and the other one does not, comparing the methylation levels and regions of residence, along with other social and environmental variables. In the twelve initial twins enrolled, it was found that *Foxp3* gene CpG methylation differences exist in monozygotic twins discordant in asthma.

The data demonstrated that *Foxp3* CpG island (21 total islands were sequenced) methylation in peripheral blood (PB) and bronchoalveolar lavage (BAL)-

Fig. 2A

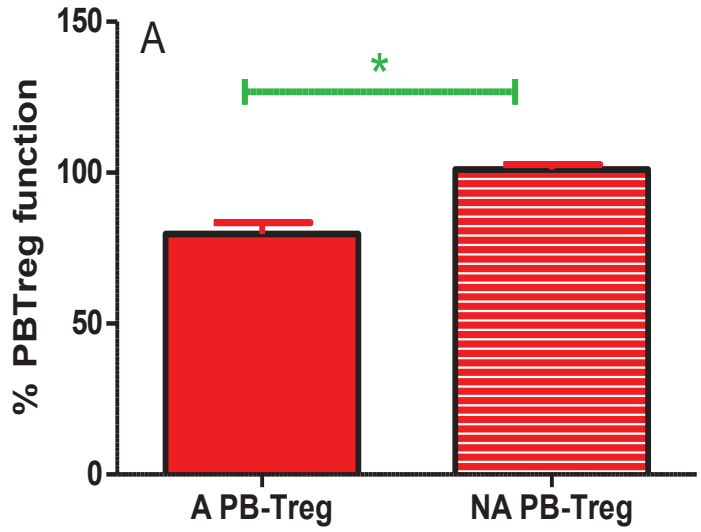

Fig. 2B

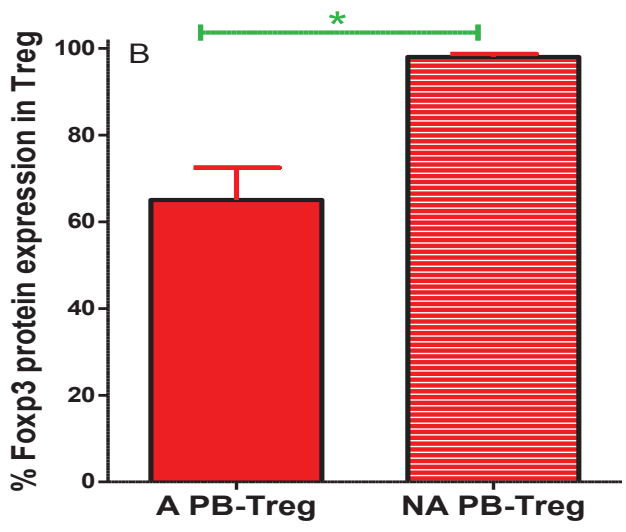

Fig. 2. Reduced Treg function and Foxp3 expression in asthmatics compared to non-asthmatics. **(A)** % PB Treg function from MZT-D pairs (n=8 pairs) as determined by quantization of suppressive activities of Treg. Bars show degree of suppression at a 1:1 ratio of conventional CD4+ T cells (effector T cells or Teff (purified for CD4+CD25) to Treg (purified for CD4+CD25hiCD127lo) (% suppression of proliferation ={(Tresp proliferation without Tregs – Tresp proliferation with Tregs)/(Tresp proliferation without Tregs)} x 100) **(B)** % Foxp3 expression in Treg as determined by presence of fluorescently labeled intracellular Foxp3 antibody in purified Treg.

purified Treg was higher in the asthmatic vs. non-asthmatic twin of the tested MZT-D pair. As a control, methylation of MZT-C twins was tested, and was found to be at similar levels for both twins (Figure 1A and B). Both PB and BAL-purified Treg were tested because in some cases of disease, Treg can have different functionality, in which PB-purified Treg could be normal and BAL-purified Treg could not, and vice-versa. By testing the areas within the airways (BAL) and away from the airways (PB), it was ensured that consistent Treg functionality was observed across different areas of the body.

Evidence was also found for methylation as a predictor of *Foxp3* expression and thus Treg function in order to further link epigenetics to differences in twin disease development. It was determined that peripheral blood Treg function as well as Foxp3 protein expression in PB Treg was lowered in the asthmatic vs. non-asthmatic twin of the tested MZT-D pair (Figure 2).

Overall, methylation was higher in asthmatics than their matched identical discordant twin. As expected, asthmatics showed reduced Treg function as well as Foxp3 protein expression when compared to their matched identical twin without asthma.

Discussion

The results suggest that the environmental exposures may play a key role in the outcome of disease development due to the varying levels of methylation, *Foxp3* expression, and Treg function in identical twins. Discordant identical twins had different levels of methylation, whereas methylation was similar in concordant twins. Our findings show that although identical twins have the same genetic makeup, their differences in health history may be attributed to varied environmental exposures that resulted in altered gene expression. Possible exposures include years of smoking (the asthmatic twin smoked while the other did not), location of residence (one twin lived in Palo Alto, whereas the asthmatic twin lived in Fresno), and so on. Our results suggest that exposure to ambient air pollutants may have led to increased methylation of the CpG island located in the *Foxp3* locus, thereby reducing *Foxp3* expression. Lowered *Foxp3* expression could lead to Treg dysfunction and insufficient inflammation, possibly resulting in the development of asthma or an increase in its severity

It is important to recognize that external environmental exposures may indeed result in genetic alterations of individuals, based on the fact that there are identical twin pairs in which one twin has developed a disease while the other one has not. However, there is insufficient information on the mechanisms in which these epigenetic processes can occur, despite the fact that climate change and chronic disease development are occurring at much faster rates in the world today. Our results imply a significant effect of methylation of the CpG locus on the outcome of disease development, especially with regards to the upstream control of gene expression. At the clinical level, more research must be done linking ambient air exposure to chronic disease prevalence and severity, particularly with asthma. And at the molecular level, we need to further elucidate the genes and pathways that regulate Treg function. With a better understanding of the factors that can lead to asthma, we will be able to advance its pharmacological treatment as well as develop preventative measures for susceptible individuals.

References

1. Bromberg *et al.* Epigenetic mechanisms of regulation of Foxp3 expression. Blood Journal 114.18 (2009).
2. Bromberg *et al.* Epigenetic Regulation of Foxp3 Expression in Regulatory T Cells by DNA Methylation. The Journal of Immunology 182 (2009): 259-273.
3. Lloyd *et al.* Regulatory T Cells in Asthma. Immunity 31.3 (2009).
4. Nadeau *et al.* Ambient air pollution impairs regulatory T-cell function in asthma. Journal of Allergy and Clinical Immunology 126.4 (2010).
5. Tager *et al.* Fresno Asthmatic Children's Environment Study (FACES) Final Report. April 2006. December 2010 <http://www.arb.ca.gov/research/apr/past/99-322.pdf>.

Leslie Cachola is a senior majoring in Human Biology with a concentration in Global Health and Infectious Disease and a minor in Creative Writing. A former Artistic Director of Dv8 Dance Troupe, music has always played a big role in her life, aside from reading books and eating ice cream. Leslie plans to spend the next two years pursuing some sort of music career and volunteering abroad with a public health focus before attending medical school.

Addressing coral tissue regeneration and bleaching with ascorbic acid supplementation

Caleb Kruse

Coral reefs face major environmental threats, two of which are overcollection and coral bleaching. Overcollection is the practice of taking coral from the reefs at a faster rate than it can be naturally replenished, and coral bleaching is a syndrome in which heat-stressed corals die from the release of their symbiotic algae zooxanthallae. This experiment aimed to increase the survival rate of fragmented coral by increasing the speed of tissue regeneration. Through supplementation of pH balanced ascorbic acid, it was shown that when fragmented coral are supplemented with 1.0 mg/L of ascorbic acid, tissue regeneration occurred more rapidly. This research further aimed to reduce the rate of heat-induced zooxanthellae expulsion through supplementation of ascorbic acid, and it was shown that coral supplemented with 1.0mg/L of ascorbic acid had an expulsion rate of zooxanthallae four times lower than that of the unsupplemented coral.

Coral reefs, one of Earth's most beautiful ecosystems, are home to an astonishing array of biodiversity with 32 of the 34 recognized animal phyla present (Wilkinson, 2002). This diversity is being utilized to find new cancer fighting drugs such as sarcophytols A and B (Fujiki, Suganuma and Suguri, 1989), and eleutherobin (Long, Carboni and Wasserman, 1998).

Reefs are also essential to the communities which surround them, providing the approximately 450 million people that live within 60 kilometers of a coral reef with a source of livelihood (Clive, 2006). Coral reefs provide large economic benefits for these communities with a total net benefit of approximately 30 billion USD per year and a net present value of approximately 800 billion USD (Cesar, Burke and Pet-Soede, 2003).

Although reefs are highly valued, they are in danger. Already 27% percent of the reefs worldwide have been destroyed (Cesar, Burke and Pet-Soede, 2003), and 58% of the remaining reefs are at risk due to human activity (Bryant, Lauretta and McManus, 1998). Currently, two main threats to coral reefs are overexploitation and coral bleaching. Research was conducted to address these problems using ascorbic acid as the method of remediation.

Overexploitation

Overexploitation is the unsustainable collection practice of local fishermen. This may cause an unnatural predator-prey relationship resulting from fishermen collecting a certain type of fish, or by collecting coral at a faster rate than it can naturally reproduce; such practices are destroying the coral reefs. It is estimated that 36% of reefs worldwide are affected by this problem (Bryant, Lauretta and McManus, 1998). Annually, approximately 11-12 million pieces of coral are exported from natural reefs (Wabnitz, Taylor and Green, 2003). This leaves a deficit of natural coral, thus harming the overall reef health.

When studying soft corals, marine scientists are faced with a predicament. Since propagating corals in a captive environment has been largely unsuccessful, the only way to obtain coral for research is to take from the reefs. An alternative to collecting from natural reefs is captive propagation, but this comes with its own set of problems. In a captive environment, sexual propagation of coral is nearly impossible due to the need to mimic the exact conditions that exist on a natural reef (Borneman, 2001). An alternative is to encourage asexual propagation using a technique called fragmentation (Highsmith, 1982). This is a process in which part of the parent coral is cut off and both the fragment and parent regenerate into full colonies. Although fragmenting is easily conducted with stony corals, the soft corals often do not survive due to a long recovery time and high risk of deadly infection.

Coral Bleaching

Rising seawater temperatures are one of the largest threats to coral reefs. 32.8% of corals are at elevated risk of extinction due to the increased sea surface temperatures, a drastic increase from previous decades (Carpenter, Abrar and Aeby, 2008). Increased water temperatures are a threat to a coral as it causes "bleaching," the release of the coral's symbiotic algae zooxanthellae (*Symbiodinium sp.*). This often causes the death of the coral since the zooxanthallae is responsible for up to 90% of the coral's energy requirements (Marshal and Schuttenberg, 2006); thus, the expulsion of zooxanthallae results in a mortality rate for the coral of over 90% (Global Coral Reef Monitoring Network, 2004). Bleaching events have proved devastating for coral reefs, most notably in the mass bleaching event of 1998, which severely damaged 16% of the world's reefs and killed approximately half of the reefs in the Indian Ocean and surrounding South Asia (Global Coral Reef Monitoring Network, 2004). From 1876-1979 only three bleaching events have occurred (Wellington, Glynn and Strong, 2001), but in the following 38 years, dozens of minor events have been reported (Lesser, 2007). Unfortunately, bleaching is only likely to increase in frequency in coming years due to the rising global temperatures (Hansen, Sato and Ruedy, 2006). Unless coral can build up an increased thermal tolerance of 0.2-1.0˚C per decade, mass-bleaching events will occur annually (Donner, Skirving and Little, 2005).

Experimental Purposes

This research had two goals. The purpose of the first experiment was to determine the effects of ascorbic acid on the rate of tissue regeneration and the survival rates of fragmented soft corals. The purpose of the second experiment was to determine the effects of ascorbic acid on the rate of zooxanthellae expulsion in coral exposed to increased water temperatures and to monitor the concentration of zooxanthellae present in the coral throughout the bleaching process.

Methodology

Experiment I

The experiments were conducted in 45-liter aquariums filled with artificial seawater. This offered increased consistency between tests, and allowed for consistency in the ascorbic acid concentration added to the

water. The following parameters were tested and maintained at the following levels in all experiments to ensure consistency and mimic the properties of natural seawater: specific gravity was maintained between 1.024-1.025, the nitrate level must remain below 5 parts per million (ppm), pH was kept between 8.40-8.50, carbonate hardness was held in a range of 9-11 degrees carbonate hardness (dKH), and temperature was kept between 25 and 27 degrees Celsius. The two experiments were run in series, starting with the testing on coral tissue regeneration rates, and moving to the tests on coral bleaching.

The first fragmenting subjects were coralimorphs from the genus *Actinodiscus*. In a culturing aquarium, scissors were used to cut the column of the coralimorph. After this incision was performed the coral was removed from the aquarium and placed on a dissection mat. The coralimorph was then severed with a scalpel into two equal parts, ensuring each fragment contains portion of the mouth, which is present on the oral disk, and a portion of the stomach, which is located in the column. This was repeated on six coralimorphs until twelve fragments were obtained. The fragments were then placed into three Petri dishes filled with a reef rubble substrate. Fine mesh netting was then placed over the top of each Petri dish to keep the fragments in place, and one Petri dish was then placed in each of the aquariums. Aquarium 1 was then supplemented with 0.28 mg/L of aqueous pH balanced ascorbic acid; Aquarium 2 was supplemented with 0.56 mg/L of ascorbic acid; and Aquarium 3 was not supplemented and used as a control. Throughout the experiment, this supplementation continued once daily, at the same concentration. To observe the rate of tissue regeneration in the coralimorphs, measurements were taken using a caliper every other day throughout the 22-day testing period.

The next test fragments were Pulsing Xenia (*Xenia sp.*). To fragment, scissors were used to cut the column of the *Xenia*. A total of ten fragments were cut, and placed in empty Petri dishes, which were placed in three new aquariums. Aquarium 1 of the *Xenia* test was supplemented with 1.0 mg/L of ascorbic acid daily, Aquarium 2 with 1.5 mg/L of ascorbic acid daily, and Aquarium 3 with no supplementation, which served as a control. Since the polyps of *Xenia* pulsate, accurate growth measurements are exceedingly difficult (Benayahu, Berner and Achituv, 1989). For this reason, tissue regeneration was observed by measuring the speed of attachment. This was measured every four hours throughout the 120-hour trial.

The final fragmenting subject was the Finger Leather coral (*Sinularia flexibilis*). The *Sinularia* was fragmented using scissors to cut a "branch" of the coral, and this was repeated until six fragments were obtained. Again the fragments were placed in Petri dishes filled with reef rubble substrate. These were then placed in the final set of testing aquarium. Ascorbic acid dosing was the same as the *Xenia* experiment, supplementing Aquariums 1, 2 and 3 with 1.5 mg/L, 1.0 mg/L, and 0 mg/L of ascorbic acid respectively. To observe health and tissue regeneration, the fragments were again measured using a caliper every other day over the 12-day testing period.

Experiment II

The aquariums were prepared in the same manner as the previous experiment with the exception of temperature. The water temperature of the aquarium serving as the control was kept at a standard 25˚C, while the temperature of the other two aquariums was raised to 32˚C, the bleaching threshold for most corals (Glynn and D'Croz, 1990). Three different types of coral were used for testing: green *Montipora capricornis*, red *Montipora capricornis*, and *Montipora undata*. Each of these coral was fragmented into 24 1-cm^2 pieces using a dremel tool, and eight fragments of each species were placed into the three aquariums. Throughout the experiment, one of the aquariums with increased water temperatures was supplemented daily with 1.0 mg/L of ascorbic acid.

To determine the rate of zooxanthellae expulsion, a count of zooxanthellae present in the coral was conducted. To do this, the zooxanthellae needed to be isolated, and this was done following a similar procedure used to isolate guard cell protoplasts from the epidermis of *Vicia fabia* leaves (Kruse, Zeiger and Tallman, 1989). Every two hours throughout experimentation, one fragment from each aquarium was removed and placed separately in a blender with 10 mL of saltwater, and blended for 90 seconds while the blender was shaken vigorously. This process homogenized the calcium carbonate "skeleton" of the coral, while leaving the zooxanthellae cells intact. This mixture was then placed in a test tube for enumeration.

The zooxanthellae solution was shaken to avoid settling of the solid material to the bottom. A syringe was used to extract a

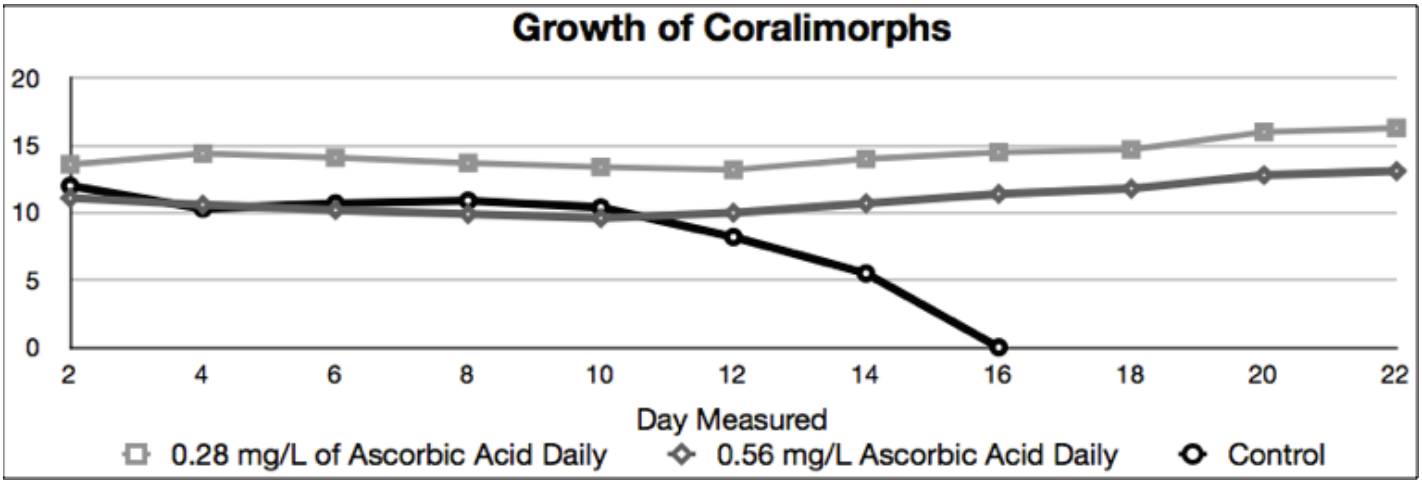

Fig. 1 Growth of supplemented and unsupplemented coralimorphs in an aquarium with ascorbic acid concentration 0.28 mg/L.

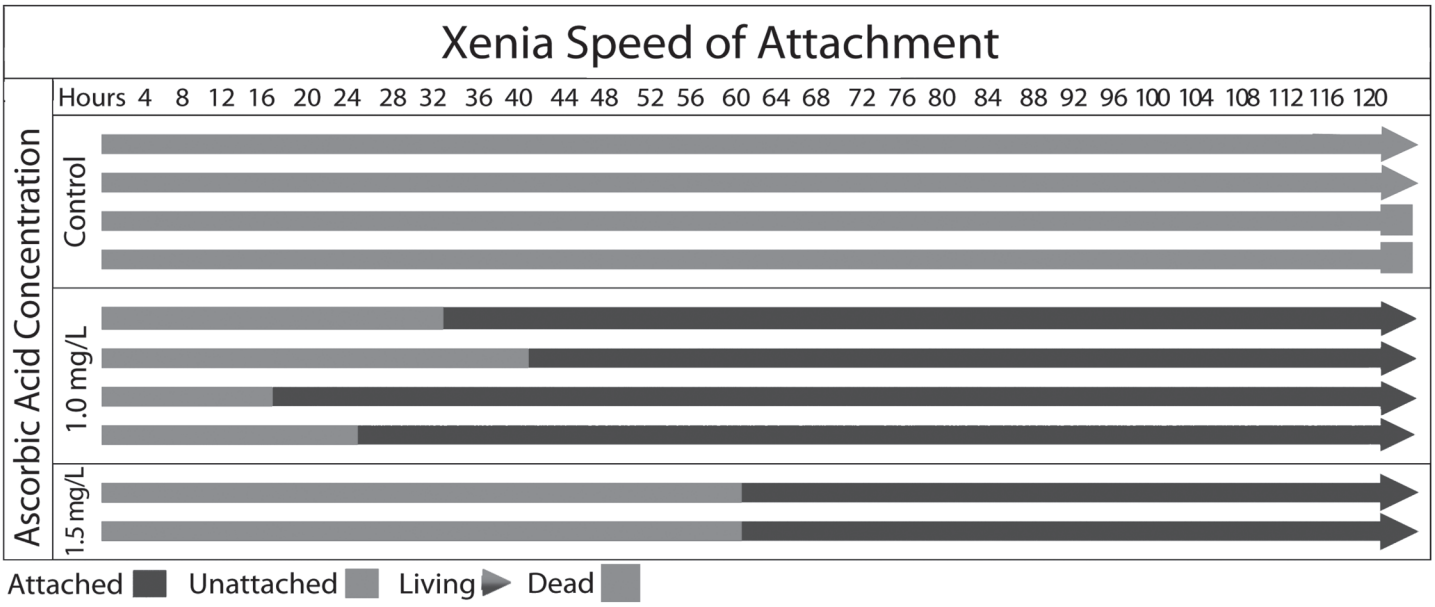

Fig. 2 Attachment time of Xenia fragments, unsupplemented and supplemented with 1/0 mg/L and 1.5 mg/L of ascorbic acid.

10 µL sample of solution, which was then placed onto a hemocytometer. The sample was observed under 100-power microscope magnification, and a photograph was taken. The zooxanthellae located in the hemocytometer grid were then counted. To determine the zooxanthellae concentration, the following formulas were used:

$$Dilution(D) = \frac{V_{New}}{V_{Old}}$$

$$Concentration(C) = D\frac{N}{V}$$

This process of homogenization and enumeration was continued bi-hourly throughout the first 12-hours of experimentation, with a final measurement at the twentieth hour.

Results

Experiment I

In the aquarium with an ascorbic acid concentration of 0.28 mg/L the four coralimorph fragments grew an average of 2.7 mm in diameter over the course of the 22-day measurement period, with all fragments surviving. The fragments supplemented with 0.56 mg/L of ascorbic acid grew an average of 2.0 mm in diameter. Again all fragments survived. The unsupplemented fragments in the control, decreased in size until the 16th day upon which all four fragments had died.

The average attachment time of the four Xenia fragments, which were supplemented with 1.0 mg/L of ascorbic acid daily, was 28 hours. The two fragments supplemented with 1.5 mg/L of ascorbic acid daily, both attached in 60 hours. Finally, the four unsupplemented control fragments did not attach throughout the 120-hour observation period, and only two of the original four fragments survived.

The two *Sinularia flexibillis* fragments that were supplemented with 1.0 mg/L of ascorbic acid daily, grew a total of 15 mm over the 12-day trial. In the group of *S. flexibillis* supplemented with 1.5 mg/L of ascorbic acid, one showed no growth, decreasing 1 mm over the testing period, while the other fragment decreased in size until the sixth day when it died. The two fragments in the unsupplemented control, decreased in size steadily throughout experimentation until death on days eight and twelve.

From these tests on three separate species of soft coral fragments it can be concluded that ascorbic acid increased the speed of tissue regeneration, and as a result, increased the survival rate of fragmented soft corals. It was also observed that 1.0 mg/L of daily ascorbic acid supple-

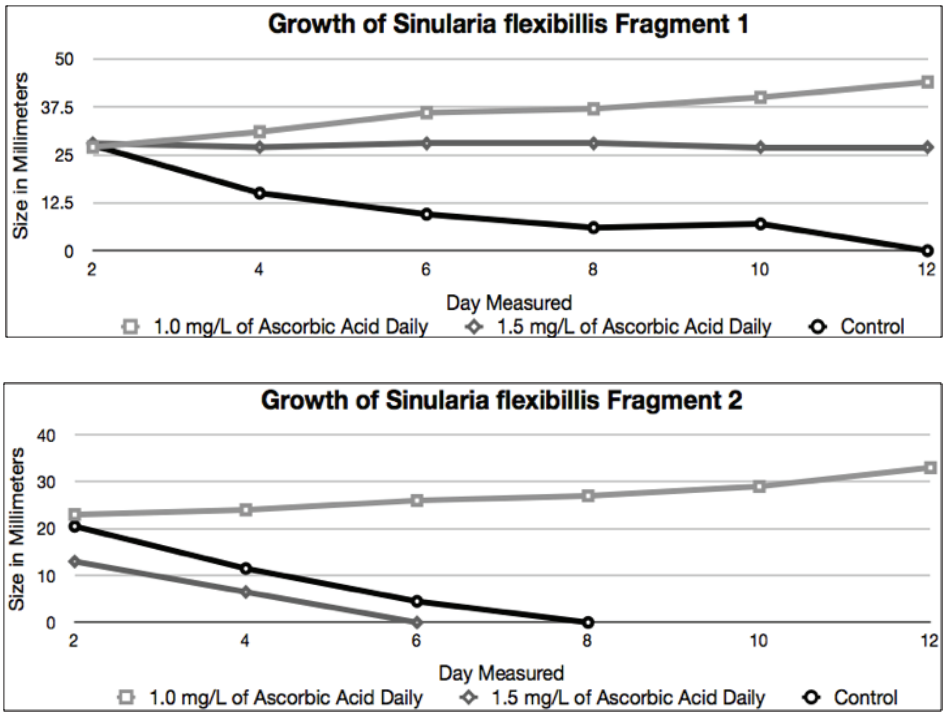

Fig. 3 Daily growth of Sinularia flexibillis fragments unsupplemented and supplemented with 1.0 mg/L and 1.5 mg/L of ascorbic acid.

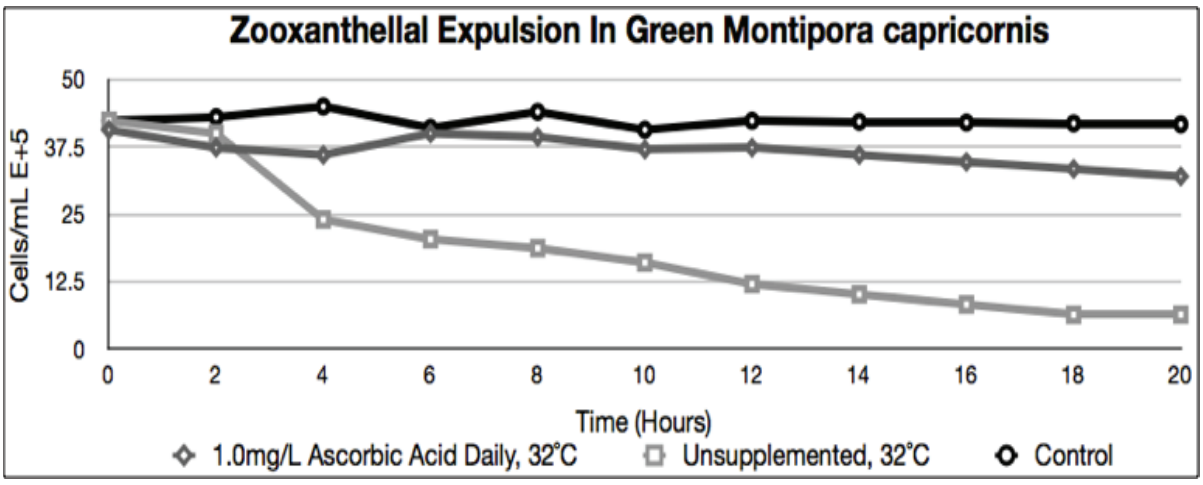

Fig. 4 Rate of zooxanthellal expulsion in supplemented and unsupplemented fragments of green *Montipora capricornis*.

mentation was optimal (in regards to the concentrations tested) for increasing tissue regeneration and survival rate of the fragments.

Experiment II

The zooxanthellae concentration in the unsupplemented fragments of green *Montipora capricornis*, which were subjected to bleaching temperatures, decreased steadily throughout the 20-hour testing period from the initial concentration of 4.2×10^6 cells/mL to 6.0×10^5 cells/mL, an average expulsion of 1.8×10^5 cells/mL each hour. The fragments supplemented with 1.0 mg/L of ascorbic acid and kept at bleaching temperatures of 32˚C retained much more zooxanthellae. The initial zooxanthellae concentration was 4.1×10^6 cells/mL and decreased to 3.2×10^6 cells/mL. This calculates to an average expulsion of 4.3×10^4 cells/mL hourly, an expulsion rate over four times slower than the unsupplemented coral. Finally, the zooxanthellae concentration in the fragments in the control, which were unsupplemented and kept at a natural temperature of 25˚C, remained steady throughout experimentation starting and ending experimentation with a 4.2×10^6 cell/mL concentration.

In the red *Montipora capricornis* the control again remained essentially unchanged, increasing from 4.0×10^6 cells/mL to 4.1×10^6 cells/mL. The zooxanthellae concentration of the unsupplemented group kept at 32˚C once again steadily decreased throughout testing, losing an average of 1.6×10^5 zooxanthellae cells/mL every hour. The supplemented coral had a much higher tolerance to the heat, with a loss of only 1.2×10^6 cells/mL throughout the entire test, averaging a zooxanthellae loss of 6.3×10^4 cells/mL hourly.

The purple *Montipora undata* had similar expulsion rates as the coral in previous experiments. The concentration of zooxanthellae remained steady in the control, dropping from 4.1×10^6 cells/mL to 4.0×10^6 cells/mL. The unsupplemented increased temperature group retained only 17% of its original zooxanthellae, decreasing from 4.1×10^6 cells/mL to 7.0×10^5 cells/mL at an average rate of 1.7×10^5 cells/mL hourly. The zooxanthellae concentration in the group supplemented with ascorbic acid did not decrease, but in fact increased from 4.1×10^6 cells/mL to 4.2×10^6 cells/mL, a remarkable gain when compared with the rates of expulsion in the unsupplemented fragments.

Observing the data collected on the three types of coral tested, it can be concluded that supplementation of 1.0 mg/L of ascorbic acid daily greatly decreases the rate of zooxanthellae expulsion in heat stressed coral, thus greatly reducing coral bleaching.

Discussion

The Role of Ascorbic Acid in Tissue Regeneration

Ascorbic acid was the chosen method of increasing the rate of tissue regeneration due to its key role in the production of healthy collagen (Kramer, Fillios and

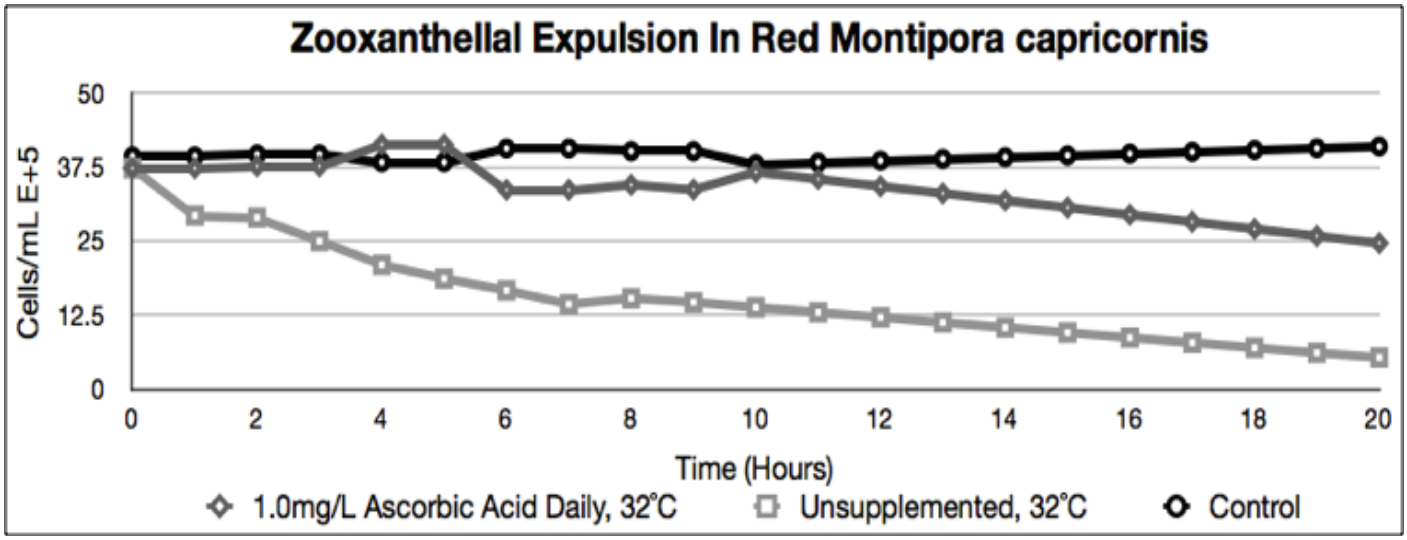

Fig. 5 Rate of zooxanthellal expulsion in supplemented and unsupplemented fragments of red *Montipora capricornis*.

Bowler, 1979). To produce collagen, the amino acid proline must become oxidized in a process called hydroxylation (Mussini, Hutton Jr. and Udenfriend, 1967). This forms hydroxyproline, an essential element of collagen. Iron is necessary to perform the oxidation, and uses ascorbic acid to return iron to its necessary oxidized state. Without ascorbic acid the hydroxylation cannot be carried out completely, leading to weakened collagen. (van B. Robertson and Schwartz, 1953). Because collagen is necessary for wound repair (van B. Robertson and Schwartz, 1953), ascorbic acid was chosen to aid tissue regeneration.

Importance of Experiment I

As mentioned previously, overcollection of coral is a major threat to the reefs. This research makes fragmenting a more viable method of obtaining soft corals. Instead of collecting from a natural reef, fragmenting can now be used with a higher success rate. Many reef aquarium hobbyists have utilized this research by fragmenting their own coral instead of buying coral collected from the reefs.

This research could also aid in the healing of damaged natural reefs because wounded coral is in need of rapid tissue regeneration. Ascorbic acid could be supplemented to a natural reef to benefit the coral in their recovery process. Furthermore, because ascorbic acid increased the rate of tissue regeneration, we know that collagen is produced during wound repair.

The Role of Ascorbic Acid in Coral Bleaching

It is thought that coral bleaching is caused by oxidative stress brought about by increased temperatures (Downs, Fauth and Halas, 2002). When temperatures increase, zooxanthellae become hyperproductive. Since zooxanthellae is photosynthetic, it produces higher amounts of oxygen (O_2), which is absorbed into the coral tissues. Some of this oxygen reacts to form hydrogen peroxide (H_2O_2) which is a harmful oxidant, and in the presence of iron, a trace element in seawater at a concentration of 3 mg/L (Armstrong, 1957), breaks down into the free radical of the hydroxyl ion (OH^-) (Goldstein, Meyerstein and Czapski, 1993). This presents a double bind for the coral. If it retains the zooxanthellae, the concentration of H_2O_2 and OH^- increase to levels high enough to kill the coral, and if it releases the zooxanthellae, it will often die of starvation (Jones, Hoegh-Guldberg and Larkum, 1998). Ascorbic acid was used in the experimentation because it is a natural antioxidant and greatly reduces or eliminates the free radical effects of the hydroxyl ion, and the resulting oxidative effects of hydrogen peroxide (Deutsch, 1998), thus allowing the coral to retain its zooxanthallae.

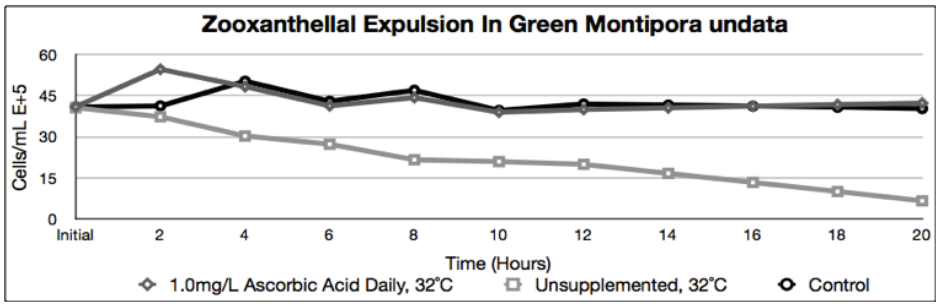

Fig. 6 Rate of zooxanthellal expulsion in supplemented and unsupplemented fragments of green *Montipora undata*.

Importance of Experiment II

The significant decrease in the rate of zooxanthellae expulsion is a significant breakthrough in the prevention of the bleaching on natural coral reefs. A current proposal to stop coral bleaching by Ove Hoegh-Guldberg, a leading coral reef researcher, is the construction of structures to shade the reefs to reduce the effects of high temperatures (University of Queensland, CRC Reef Research Centre, 2008). Supplementation of ascorbic acid could be used to defend reefs that have a high risk of a bleaching event.

A further contribution of the research is the enumeration of the rate of zooxanthellae expulsion in heat stressed coral. This rate is currently unknown in many species of coral, but through this experiment the rate of zooxanthellaee expulsion in green *Montipora capricornis*, red *Montipora capricornis*, and green *Montipora undata* are now documented.

The zooxanthellae isolation technique developed in this experiment is a novel method that is far simpler than methods currently used. This could aid in the research of coral bleaching, zooxanthellae, and the rates of zooxanthellae expulsion in heat stressed coral.

Conclusion

These findings could prove to be remarkably beneficial to the aid of threatened coral reefs. Already the method of increasing the survival rate of propagated coral is being used by many marine aquarium hobbyists throughout the United States, thus reducing the amount of coral being taken from natural reefs. As mentioned previously, the current method to slow or stop coral bleaching is to shade reefs that are at high risk of bleaching events. Supplementation of coral reefs with pH balanced ascorbic acid could be a simpler, more cost effective method of reducing coral bleaching on reefs with high bleaching risks. Reduced calcification of coral reefs has devastated natural reefs to such great extent that electrified grid structures are being constructed called biorock. Through electrolysis, the electrified grid breaks down H_2CO_3 into H_2 and CO_3, the carbonate ion then binds with calcium to create $CaCO_3$. There are currently eight artificial reefs constructed of this biorock with sizes up to 220 meters long, but the process is obtrusive, and the artificial calcification is slow (Henderson, 2006). Ascorbic acid supplementation to these reefs to increase calcification would again be a simpler, more cost effective method to aid reefs at high risk of acidification. Supplementation of ascorbic acid to natural coral reefs would provide a threefold benefit of increased wound repair, calcification, and resistance to raised temperatures.

References
1. Armstrong, F. A. J. "The Iron Content of Sea Water." Journal of Marine Biology 36 (1957): 509-517.
2. Benayahu, Y, T Berner and Y Achituv. "Development of planulae within a mesogleal coat in the soft coral Heteroxenia fuscescens." Marine Biology 100.2 (1989): 203-210.
3. Borneman, Eric H. Aquarium Corals, Selection Husbandry and Natural History. Neptune City: T.F.H. Publications, Inc., 2001.
4. Bryant, Dirk, *et al*. Reefs at Risk: A Map-Based Indicator of Threats to the World's Coral Reefs. Washington, D.C.: World Resources Institute (WRI), 1998.
5. Carpenter, Kent E, *et al*. "One-Third of Reef-Building Corals Face Elevated Extinction Risk from Climate Change and Local Impacts." Science 321.5888 (2008): 560-563.
6. Cesar, Herman, Lauretta Burke and Lida Pet-Soede. The Biodiversity Benefits of Coral Reef Ecosystems: Values and Markets. Zeist: Cesar Environmental Economics Consulting (CEEC), 2003.
7. Clive, Wilkinson R. "Global Change and Coral Reefs: Impacts on reefs, economies and cultures." Global Change Biology 2.6 (2006): 547-558.
8. Deutsch, John C. "Ascorbic Acid Oxidation by Hydrogen Peroxide." Analytical Biochemistry 255.1 (1998): 1-7.
9. Donner, Simon D, *et al*. "Global assessment of coral bleaching and required rates of adaptation under climate change." Global Change Biology 11.12 (2005): 2251-2265.
10. Downs, C. A., *et al*. "Oxidative stress and seasonal coral bleaching." Free Radical Biology and Medicine 33.4 (2002): 533-543.
11. Fujiki, Hirota, *et al*. "Sarcophytols A and B inhibit tumor promotion by teleocidin in two-stage carcinogenesis in mouse skin." Journal of Cancer Research and Clinical Oncology Volume 115.Number 1 (1989): 25-28.
12. Global Coral Reef Monitoring Network. Status of Coral Reefs of the World: 2004. Ed. Clive Wilkinson. Vol. I. Townsville: Australian Institute of Marine Science, 2004. II vols.
13. Glynn, P. W. and L. D'Croz. "Experimental evidence for high temperature stress as the cause of El Niño-coincident coral mortalit." Coral Reefs 8.4 (1990): 181-191.
14. Goldstein, Sara, Dan Meyerstein and Gidon Czapski. "The Fenton reagents." Free Radical Biology and Medicine 15.4 (1993).
15. Hansen, James, *et al*. "Global Temperature Change." Procedings of the National Academy of Sciences 103.39 (2006): 14288-14293.
16. Henderson, Caspar. "Electric Reefs ." New Scientist (2006).
17. Highsmith, Robert C. "Reproduction by Fragmentation in Corals." Marine Ecology Progress Series 7 (1982): 207-226.
18. Hoegh-Guldberg, Ove and G. Jason Smith. "The effect of sudden changes in temperature, light and salinity on the density and export of zooxanthellae from the reef corals Stylophora pistillata Esper and Seriatopora hystrix Dana." Journal of Experimental Marine Biology and Ecology 129 (1989): 279-303.
19. Hoegh-Guldberg, Ove, *et al*. "Coral Reefs Under Rapid Climate Change and Ocean Acidification." Science Magazine 318.5857 (2007): 1737-1742.
20. Jones, R., *et al*. "Temperature induced bleaching of corals begins with impairment of dark metabolism in zooxanthellae." Plant Cell and Environment (1998): 1219-1230.
21. Kramer, Gerald M, Louis C Fillios and Edward C Bowler. "Ascorbic Acid Treatment on Early Collagen Production and Wound Healing in the Guinnea Pig." Journal of Periodontology (1979): 189-192.
22. Kruse, Tamara Sue, Eduardo Zeiger and Gary Tallman. "Isolation of Guard Cell Protoplasts from Mechanically Prepared Epidermis of Vicia faba Leaves." Plant Physiology (1989): 1382-1386.
23. Lesser, Michael P. "Coral reef bleaching and global climate change: Can corals survive the next century?M M E." Procedings of the National Academy of Sciences 104.13 (2007): 5259-5260.
24. Long, Byron H, *et al*. "Eleutherobin, a Novel Cytotoxic Agent That Induces Tubulin Polymerization, Is Similar to Paclitaxel (Taxol®)." Cancer Research 58 (1998): 1111-1115.
25. Marshal, Paul and Heidi Schuttenberg. A Reef Manager's Guide to Coral Bleaching. Townsville: Great Barrier Reef Marine Park Authority, 2006.
26. Mussini, Emilio, John J Hutton Jr. and Sidney Udenfriend. "Collagen Proline Hydroxylase in Wound Healing, Granuloma Formation, Scurvy, and Growth." Science 157.3791 (1967): 927-929.
27. University of Queensland, CRC Reef Research Centre . "Great Barrier Reef Marine Park Authority :: Research Priorities." 2008 4-May. Great Barrier Reef Marine Park Authority :: Great Barrier Reef Marine Park Authority (GBRMPA). 2009 29-September
28. Van B. Robertson, William and Barry Schwartz. "Ascorbic Acid and the Formation of Collagen." The Journal of Biological Chemistry (1953): 689-696.
29. Wabnitz, Collette, *et al*. From ocean to aquarium, The global trade in marine ornamental species. Cambridge: UNEP World Conservation Monitoring Centre, 2003.
30. Wellington, G. M., *et al*. "Crisis on coral reefs linked to climate change." Eos, Transactions, American Geophysical Union 82.1 (2001): 1.
31. Wilkinson, Clive. Status of Coral Reefs of the World 2002. Global Coral Reef Monitoring Network. Townsville: Australian Institute of Marine Science, 2002.

Caleb Kruse is a freshman from Colorado Springs, Colorado. He has a passion for life that is rooted in a fascination with the world. Caleb enjoys skiing and photography, and has recently uncovered the thrill of mountain biking on single-track paths in the Stanford foothills. He also enjoys recreational running, and has completed two marathons. Caleb loves learning and the study of new research that he finds from all disciplines. He loves sharing his passion with anyone who is interested, whether it be one of his eight siblings, or a fellow student. He hopes to continue his exploration of the world by majoring in biology

Ants and moths: Analysis of biodiversity and abundance in revegetated pastoral land

Steven Crane, C. Baker

Insect bioindicators have been used the world over, but they have seldom been used to evaluate revegetation efforts on previously pastoral land. The present study aimed to evaluate the health and biodiversity of a 3-year-old revegetated plot of previously pastoral land in Australia by comparing it to a mature forest, using ants and flying insects as bioindicators. Using ant baits and a nocturnal light trap, the study was conducted at these two sites over the course of two days and nights. Three genera of ants were found in the mature forest, and one (Ochetellus) was found in the revegetated forest, but in much greater abundance than in the mature forest. Ochetellus also exhibited superior recruitment over the other ants. Greater abundance but lower diversity was also seen in the flying insect results, with 32 morphospecies across 6 orders present in the mature forest, compared to 18 morphospecies in the revegetated forest. These results were interpreted considering physical and biological differences between the sites, the limitations of light traps, and ants' and flying insects' applicability as bioindicators.

The relationship between modern agriculture and native vegetation is often exploitative and disruptive to the natural processes at work, but humans occasionally seek to restore previously disturbed habitats to their original state. In doing so, biological indicators, or bioindicators, are useful for informing environmental managers or rehabilitators about the success of restoration efforts. While an abundance of literature exists on bioindicator work with rehabilitated mine sites and sand dune systems, relatively little work has focused on previously pastoral or agricultural rehabilitation efforts, especially relating to rainforests (Majer, 1983; Majer & Nichols, 1998; Campbell, 1998; Nakamura, Proctor, & Catterall, 2003).

In seeking to assess the health of a revegetated plot of previously agricultural land, the present study used ants and nocturnal flying insects as bioindicators. A good bioindicator species should be highly correlated with the diversity of other organisms in an environment, have a specific habitat niche, exhibit sensitivity to disruption of the habitat, and be easy to collect and identify (Angelstam, 1998; Armbrecht & Ulloa-chaco, 2003). Fortunately, ants (family Formicidae) and moths (order Lepidoptera) both fulfill this role well. In fact, in a review of different bioindicator species, ants and Lepidoptera came out on top as the most useful and suitable bioindicators for forests (Armbrecht & Ulloa-chaco, 2003). Lepidoptera diversity is especially well-correlated with overall habitat quality and ants specifically are highly correlated with the abundance, richness, and composition of the flora and other invertebrates with which they share a biological system (Uehara-Prado & Freitas, 2009; Majer, 1985). In short, with a comprehensive knowledge of the ants or moths in a system, one also has a good understanding of the diversity of the other organisms and the overall health of an ecosystem.

Furthermore, beyond serving as an indicator of other ecosystem processes, ants (and other invertebrates) are themselves essential for ecosystem health, providing services such as soil aeration and drainage, litter decomposition, nutrient cycling, pollination, and (a task especially characteristic of ants) seed distribution (Majer, 1985). Accordingly, the overall diversity of insect orders seen in an ecosystem is obviously a direct indicator of ecosystem diversity. It should be noted, however, that most of the background on using ants and flying insects as bioindicators in Australia has focused on mine site rehabilitation, and their applicability to reforested farmland has a limited literature, to which the present study might contribute (Nakamura, Proctor, & Catterall, 2003).

From an abundance of previous literature comes a few of the important background characteristics of the three genera of ants represented in the present study: Pheidole, Iridomyrmex, and Ochetellus. For one, Pheidole is not an abundant species in habitats annually disturbed by fire, but Iridomyrmex is, leading to the prediction that Pheidole would not be present in the revegetated site (which was "disturbed" and planted only three years ago) while the Iridomyrmex might be (Andersen, 1991). Pheidole is also reported to be a highly competitive genus with colonies operating with great efficiency, so one might expect its numbers to be higher than those of other ants when both are found in the same area (Anderson, 2000). For Ochetellus, a slight discrepancy exists in the literature. Some have found Ochetellus, an opportunist, to be characteristic of disturbed sites: a ruderal specialist (it is one of the first species to colonize newly disturbed sites) (Andersen, 1997; King, Andersen, & Cutter, 1998). Others have found Ochetellus to be abundant in mature forests and unimportant in interacting with other ant fauna. The present study aims to shed some light on that discrepancy in the literature (Majer & Nichols, 1998).

Working on a revegetated forest site and a mature forest site, the present study aimed to investigate the biodiversity of the revegetated forest by using ants and flying insects as bioindicators of overall biodiversity and health of the forest systems. Is three years a long enough time for a revegetated site to demonstrate the biodiversity typical of a mature forest stand? We predicted that it would not be. More specifically, our hypotheses were 1: that the mature rainforest would yield higher species richness (more species of ants represented in the baits and more species of flying insects represented in the traps) than the revegetated forest would; 2: that the mature rainforest would yield higher abundance in insects (higher overall numbers summed across the different species) than the revegetated forest; and 3: that the revegetated forest would have ant genera represented that are purportedly characteristic of disturbed sites such as Ochetellus or the infamous invasive African Big-Headed ant, Pheidole megencephala.

I. Methods

A. Dates and Locations

The study was conducted on October 10 and 11, 2009 at two sites on the Atherton Tablelands: one site represented the revegetated rainforest, cleared and planted three years prior, and the other represented

Genus	Mature Forest Species Composition	Revegetated Forest Species Composition
Iridomyrmex	365	0
Pheidole	548	0
Leptomyrmex	2	0
Ochetellus	0	4813

Table 1 These numbers reflect the total number of individual ants of each species found in the two forests by genus. Three genera were represented in the mature forest while only one species dominated the revegetated forest.

a patch of mature Mabi rainforest with minimal human presence. They were both located on the Bonadio family property, 4.5 miles west of Yungaburra in Northeast Queensland, Australia. The catchment for the area is the Barron River, and both sites are approximately 700m in elevation, receive 1600mm of rain yearly, and are separated by approximately 700m of river, cleared land, and other revegetation plots. The specific composition of the predominant organisms in the mature forest is unavailable, but they are typical of Mabi Rainforest on the Atherton Tablelands with a thick, multilayered canopy approximately 30-40m in height.

B. Ant Baits

In each forest, two transects were laid out on consecutive days at approximately 11:00am. Along each 25m transect, 12 baits were placed at even intervals: 6 protein (tuna) baits on one side, and 6 sugar (honey) baits on the other. The baits were checked at 30min and 60min after being placed with photographs and counts of different ant morphospecies. The ant samples were later identified down to the genus level in all cases, and species level in some.

Ant data analysis involved three factors: 1) species richness (number of ant genera), 2) relative abundance (total number of individual ants) between the two forests, broken down by genera and by overall number, and 3) recruitment compared among the different ant genera (the difference between the 60min check and the 30min check).

C. Flying Insect Traps

Light traps were set up next to the mature forest and within the revegetated forest. Collection started when the light was switched on and continued for 60 minutes. Every 10 minutes, a sample of each insect morphospecies present was captured in a plastic jar, identified to order, and given a number (*e.g.* Lepidoptera 1). At the same interval a count was also conducted of all the identified insects up to that point, providing a running tally and a total at the end for each morphospecies present. Analyzing the flying insect data involved totaling the number of each individual per morphospecies present, then totaling the number of each morphospecies per order at the end of 60min.

II. Results

A. Ant Baits

Four ant genera were identified: Iridomyrmex, Pheidole, Ochetellus, and Leptomyrmex. Ochetellus was the only genera represented in the revegetated forest. Table 1 illustrates the genera composition of the two forests. The numbers represent the sum total of the individuals of each ant genus at the 60-minute mark among all the baits between both days. While the revegetated forest had a much higher numbers of individuals, the mature forest had three genera represented, exhibiting greater biodiversity than the one genus in the revegetated forest.

Recruitment is the ability of an ant colony to mobilize its workers to a new, abundant food source. In the present study, recruitment was calculated by taking all baits that showed an increase in ants between the 30min check and the 60min check, totaling the number of individual ants in each case (sorting by genera) and subtracting to find the number of new ants on the bait at the 60min check. Baits did not have any ants at the 30min check were excluded, as the meaningful comparison is between ant genera and their ability to bring new ants to a discovered resource in a 30-minute period. Baits showing a decrease in ants were also excluded due to a possible ceiling effect in the ant bait methodology (see discussion). There were only enough baits showing this pattern for the Ochetellus and Pheidole, so the Iridomyrmex and the Leptomyrmex were omitted from the recruitment analysis

The 60min totals were also converted into a percentage of the 30min totals (Figure 1), showing that the Pheidole increased by almost 200%, on average, while the Ochetellus only increased by 146%, on average. However, when considering the absolute number of individuals involved (Figure 2), a different picture emerges: the Ochetellus brings an average of 74 more ants to the bait while the Pheidole only increases its numbers brings an average of 36 more ants. This shows that the Ochetellus were already at the baits in high numbers at the 30min mark, and were able to bring even more ants, on average, than the Pheidole.

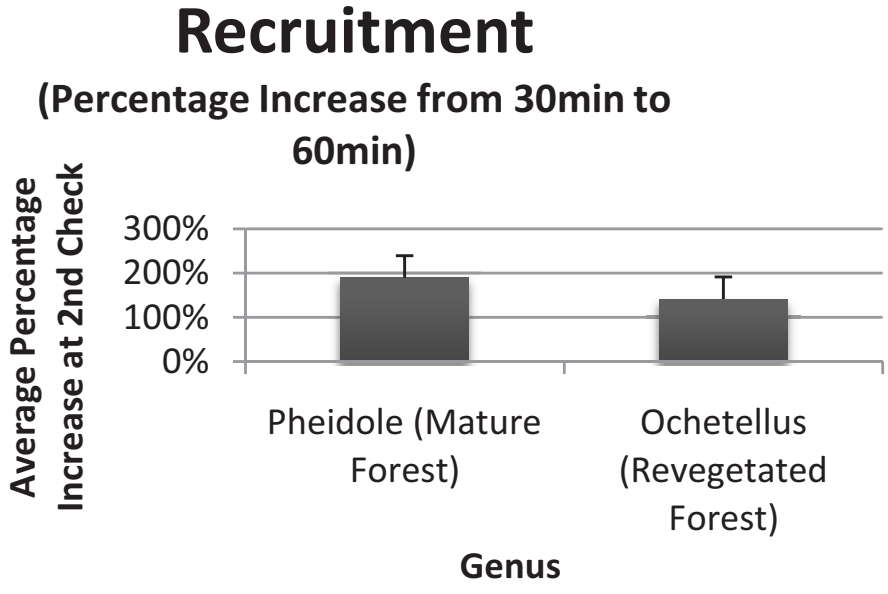

Fig. 1 The average percent increase for Pheidole and Ochetellus in baits that showed an increase from the 30min check to the 60min check with bars for standard error. Pheidole baits n=8, Ochetellus baits n=11.

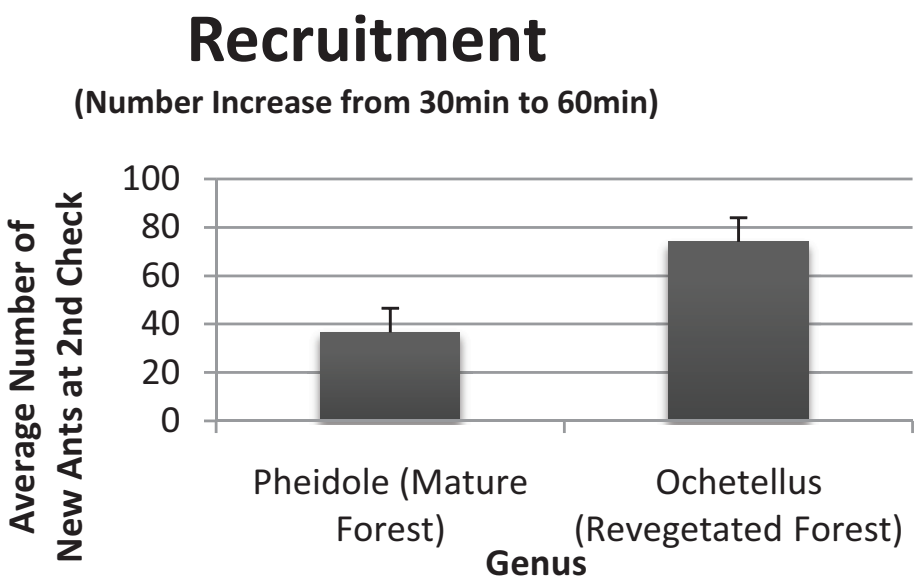

Fig. 2 Bars showing the average number of new ants for Pheidole and Ochetellus in baits that showed an increase from the 30min check to the 60min check with bars for standard error. Pheidole baits n=8, Ochetellus baits n=11.

B. Flying Insect Traps

The flying insect data trends were similar to that of the ant data: the mature forest exhibited a higher biodiversity with respect to the number of morphospecies present across six orders (Figure 3), while the revegetated forest had a far greater number of individual insects present (Figure 4), though most of those were due to one species of Diptera.

While the proportions of orders are very similar between the two forests (Figure 5), the number of morphospecies that compose those orders (Figure 4) are much lower in the revegetated forest than in the mature forest.

Diptera exemplifies one final difference between the two sites: Figure 6 shows that while the overall number of diptera is higher in the revegetated forest (128 compared to 38), the morphospecies are more evenly distributed among a higher species richness in the mature forest.

III. Discussion and Conclusion

A. Diversity and Abundance Differences

The same trend appears to permeate the data comparing the two forest types. The mature forest is characterized by a higher number of distinct morphospecies (Figures 3 and 6) and genera (Table 1) while at the same time having lower overall numbers of insects (Figure 4). The revegetated is primarily dominated by one homogenous mass of insect. In these cases it was the Ochetellus on the ground during the day and one species of Diptera in the air during the night. The results, in short, show that the revegetated forest has lower diversity with higher abundance.

Why would the mature forest, as hypothesized, support more biodiversity in both ants and flying insects? First, the mature forest is likely more productive as the canopy cover is fuller and consequently there are higher rates of photosynthesis. In addition to greater primary production (and thus greater biological energy overall), there is also a greater diversity of food types: more decaying leaves and logs which would generate the fungi with which many ants form mutualisms (Mueller, Schultz, Currie, Adams, & Malloch, 2001). Furthermore, Majer (1985) found that among a wide range of forest variables, leaf litter depth and total plant species in a plot were the strongest predictors of ant species richness, and both of these factors were higher in the mature forest. There is also a greater variety of habitat in the mature forest with taller trees, tree hollows, vines and thickets, and a multilayered canopy. With greater variety of habitat and greater food resources, the mature forest has suitable niches for a greater variety of mammals, birds, reptiles, and arthropods. When those larger fauna die, they create even greater variety and abundance of food for carnivorous ants, a variety and abundance not present in the revegetated forest.

Why would it be that the revegetated forest supports a higher abundance of insects, contrary to the second hypothesis? First, Diptera and Ochetellus likely dominate because of the specific kinds of production occurring. There are no old fallen trees to provide habitat for insects and fuel for decomposers, which in turn would provide food for different insect species. Instead, the revegetated forest consisted entirely of juvenile trees with minimal groundcover and very few ground-level plants or woody debris. Second, species richness has been shown to have an inverse relationship with mean ground temperature, and the revegetated forest plot likely had a much higher ground temperature considering the open nature of the canopy (King, Andersen, & Cutter, 1998). Third, while different species of trees were planted in the revegetated forest, the habitat is largely uniform with evenly spaced trees and a homogeneous ground cover. That makes for essentially one giant niche, and Ochetellus and the abundant Diptera sp. seem to be the most adept at occupying that niche. Lastly, it could be that the revegetated forest might not actually have the highest abundance, but that the results obtained reflect a selection bias based on limited methodology, especially with respect to the ants. Specifically, with a greater variety of food and habitat in the mature forest, an ant bait in the mature forest is less likely to attract a representative sample of ants, as some ants may live in the trees and others may be occupied with other food resources that wouldn't be present in the revegetated forest. Only with a wider array of sampling methods and increased scale of the baits could the true nature of the ant fauna in either forest be truly represented in the results.

B. Ant Genera

Fitting with the third hypothesis, the ant genus represented in the baits of the revegetated forest was indeed one typically found in sites of disturbance, the Ochetellus. One obvious reason for its permeation of the habitat is the markedly higher recruitment numbers (Figures 1 and 2) and overall numbers (Table 1) compared to other ant genera sampled. In any competitive scenario, Ochetellus would hoard resources more quickly and efficiently than the other genera. Importantly for environmental managers, these findings fall in line more with the literature on Ochetellus as a ruderal specialist instead of the literature on Ochetellus as an abundant forest genus (Andersen, 1997; Majer & Nichols, 1998). However, due to the limited scope of the present study and the low number of ant genera represented, caution should be

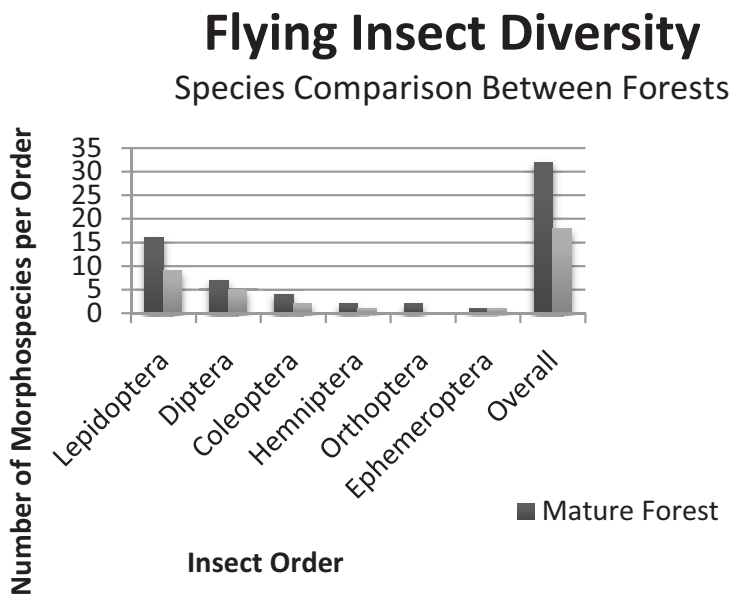

Fig. 3 The number of morphospecies counted between the mature forest and the revegetated forest separated by order.

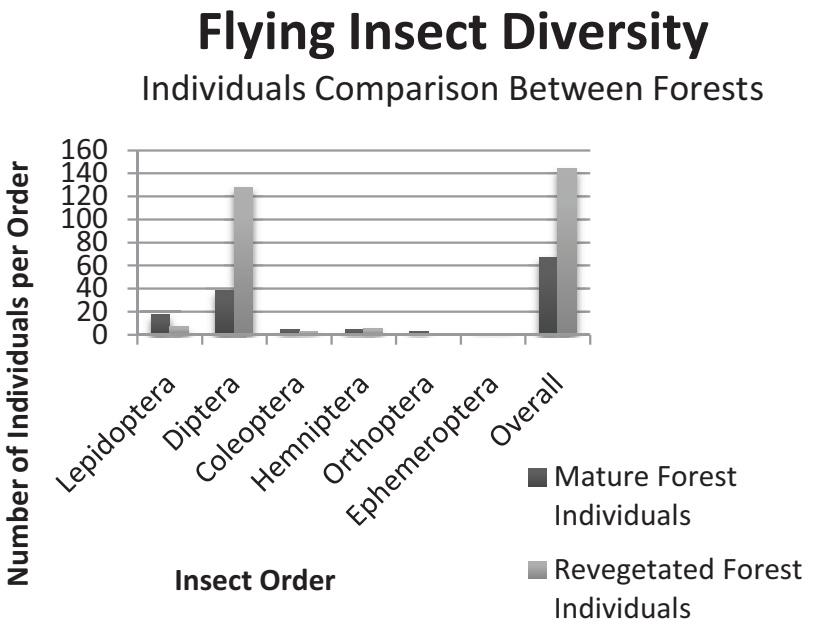

Fig. 4 The number of individual insects counted between the mature forest and the revegetated forest, separated by order.

used when extrapolating these results to the larger significance of Ochetellus as a bioindicator. Laboratory or observational research on the interactions between different species of ants could illuminate the mechanism behind the monopolization by Ochetellus of the revegetated forest: do the Ochetellus actively fight off other species, or do they simply out-compete other ants in utilizing resources, as the present study would suggest?

In the mature forest, on two occasions Iridomyrmex was seen fighting off Pheidole ants from honey baits, suggesting that Iridomyrmex lives up to its reputation as a dominant Dolichoderinae, a very aggressive ant (King, Andersen, & Cutter, 1998). However, the overall Pheidole numbers were higher than the Iridomyrmex (while absent from the revegetated plot), suggesting that its overall efficiency and competitive organization leads it to greater success (Anderson, 2000). One further reason why Pheidole may not have been present in the revegetated site is due to abiotic factors. It has been shown that Pheidole can dominate the ant population, but usually in moist environments (Hoffmann & Parr, 2007). The revegetated forest probably loses more of its rainwater to solar evaporation than the mature forest due to the thinness of the canopy.

In justification of omitting the baits that did not show an increase to produce Figures 1 and 2, consider that some of the baits swarming with hundreds of Ochetellus had noticeably less bait material between the 30min check and the 60min check, showing a ceiling effect, as they had fewer ants at 60min ostensibly because there was no longer a need to have so many ants deployed for a smaller food source, not because their recruitment had fallen short. Observations from the field suggests that the peak recruitment for the Ochetellus may have occurred only 10 minutes after the baits were set, when the bait was entirely surrounded and covered in ants, with little space for any additional ants which were indeed present on the periphery. To improve this method in the future, it would be wise to use much larger baits of a standard volume in the case of working with ants in such great abundance.

C. Using Ants and Flying Insects as Bioindicators

The present study was perhaps too limited in scope to conclude confidently the usefulness of ants as bioindicators. While three genera were present in the mature forest compared to one in the revegetated forest (Table 1), these numbers are very small and the sampling was carried out over only two days, while most studies are based on dozens of different species of ants from far more than four genera (Majer, 1983). Further, the revegetated forest ant data may over-represent Ochetellus by random chance of bait placement near their nests or foraging routes. With such small numbers of traps, it is hard to dismiss this possibility.

The flying insect data may have a more meaningful interpretation. Their composition in the two forests by order was largely similar (Figure 5), suggesting that investigations looking only at the relative abundance of orders (and not absolute abundance) would miss out on crucial differences between ecosystems. Relative order abundance, therefore, would make a poor quantity to use as a bioindicator. However, in the present study, even species richness and diversity of Diptera showed a meaningful difference between the two forest types (Figure 6), let alone the oft-used species richness of Lepidoptera. Notably, Lepidoptera was the one order that significantly defied the general trend, showing higher species richness (Figure 3) and higher abundance

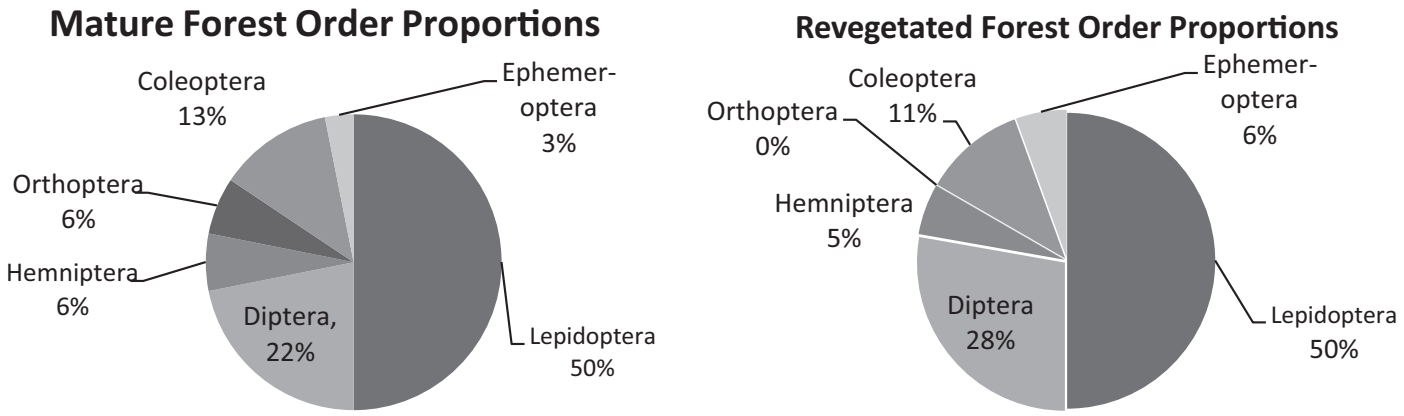

Fig. 5 The composition of the two forests as the proportion of morphospecies broken down by each order present.

(Figure 4) in the mature forest. Therefore, based on the present results combined with past literature, one might conclude that both species richness and diversity for Lepidoptera capture meaningful information regarding forest health and would serve as a good bioindicator. The other orders sampled in the present study (Coleoptera, Hemniptera, Orthoptera, and Ephemeroptera) were not present in high enough numbers, either by morphospecies (Figure 3) or by individual (Figure 4), to show significant differences between the two plots and thus would not be useful as bio-indicators based on these results. However, were this experiment expanded and the differences between morphospecies count were closer to 50 versus 70 instead of 5 versus 7, more meaningful conclusions could be reached as to their applicability as bio-indicators.

D. Limitations

Light traps are limited in their validity because they will only attract insects that both fly and usually use the moon or stars to navigate. However, not all insects use this celestial navigational method and, obviously, not all insects fly. Thus light trapping may attract an unrepresentative sample of insects.

To rectify this limitation, it is essential to use combinations of sampling methods that complement each other, because every method has similar limitations. Using an alternate method of sampling species that are known to avoid one type of trap is a wise move that could be applied to future studies of both ants and moths. For example, bait traps, different styles of backlit traps, or suction traps could be used in addition to flying insect light trapping (Uehara-Prado & Freitas, 2009; Summerville, Ritter, & Crist, 2004; Kempton & Taylor, 1974). For ants, pitfall traps, leaf litter sifting, bait sampling in different areas of the forest, or direct searching could be employed in future studies to gain a more comprehensive understanding of the diversity of ants in each system (Armbrecht & Ulloa-chaco, 2003). However, these limitations don't significantly affect the present study, as its aim was to compare the biodiversity between two habitats instead of conducting a comprehensive survey of the insect fauna present in each forest.

E. Improvements and Future Directions

To better make the case for flying insects and ants as bioindicators for previously pastoral revegetation efforts, future studies could compare revegetated plots of different ages to show the progression of insect recolonization, furthering a literature established by Nakamura, Proctor, and Catterall (2003). Further improvements include conducting larger sample sizes over greater amounts of time, utilizing multiple alternative methods, measuring physical and vegetation variables, and identifying every insect to the species level for more specific, higher-resolution data. Furthermore, were checks conducted on the ant baits every ten minutes instead

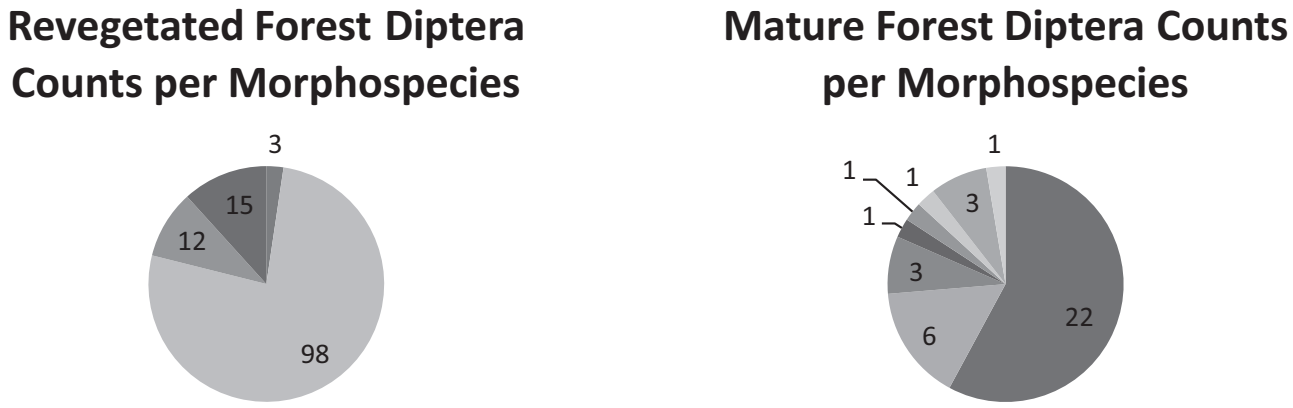

Fig. 6 The number of individuals per morphospecies of Diptera compared between the two forest types. Specific morphospecies unknown, but in each case, one morphospecies was present in much higher volume than the others.

of only twice in an hour, this higher resolution temporal data could reveal different recruitment patterns, painting a richer picture of how different species of ants utilize resources. Finally, ant baits with larger and standardized amounts of bait food would address the possible ceiling effect seen in the present study with Ochetellus recruitment.

Despite certain limitations, it is clear from the present study that using the flying insects (and especially Lepidoptera) as bioindicators has valid applicability to reforested pastoral land. The data do clearly reflect differences between the sites that logically stem from the dramatically different abiotic and biological factors between the two sites. It is also clear that it takes more than three years after a revegetation effort to foster the diversity of insects typical of a mature forest. Finally, we see that every sampling method has biases inherent to its design, attracting only certain insects. Thus, multiple sampling methods should be used produce the most valid bioindicator data.

IV. Acknowledgements

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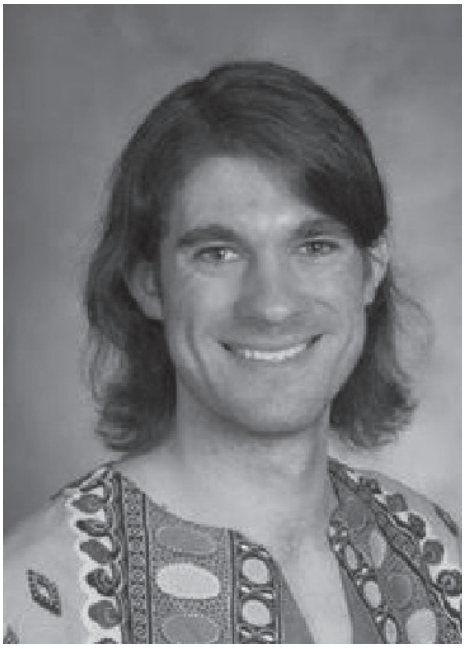
References

1. Andersen, A. N. (1997). Functional groups and patterns of organization in North American ant communities: a comparison with Australia. Journal of Biogeography, 24(4), 433-460.
2. Andersen, A. N. (1991). Responses of Ground-Foraging Ant Communities to Three Experimental Fire Regimes in a Savanna Forest ... more. Biotropica, 23(4), 575 - 585.
3. Anderson, A. N. (2000). The Ants of Northern Australia: A guide to the monsoonal fauna (p. 106). Collingwood: CSIRO.
4. Angelstam, P. K. (1998). Maintaining and Restoring Biodiversity in European Boreal Forests by Developing Natural Disturbance Regimes. Journal of Vegetation Science, 9(4), 593-602.
5. Armbrecht, I., & Ulloa-chaco, P. (2003). The Little Fire ant. Museum, (Kempf 1972), 542-547.
6. Campbell, C. L. E. E. (1998). Using Ant Species (Hymenoptera: Formicidae) as a Biological Indicator of Agroecosystem Condition, (1993), 1102-1110.
7. Hoffmann, B. D., & Parr, C. L. (2007). An invasion revisited: the African big-headed ant (Pheidole megacephala) in northern Australia. Biological Invasions, 10(7), 1171-1181. doi: 10.1007/s10530-007-9194-x.
8. Kempton, R. A., & Taylor, L. R. (1974). Log-Series and Log-Normal Parameters as Diversity Discriminants for the Lepidoptera. Journal of Animal Ecology, 43(2), 381-399.
9. King, J. R., Andersen, A. N., & Cutter, A. D. (1998). Ants as bioindicators of habitat disturbance: validation of the functional group model for Australia's humid tropics. Specialist, 1638.
10. Majer, J. D. (1983). Ants: Bio-indicators of minesite rehabilitation, land-use, and land conservation. Environmental Management, 7(4), 375-383. doi: 10.1007/BF01866920.
11. Majer, J. D. (1985). Recolonization by ants of rehabilitated mineral sand mines on North Stradbroke Island, Queensland, with particular refernce to seed removal.
12. Majer, J. D., & Nichols, O. G. (1998). Long-Term Recolonization Patterns of Ants in Western Australian Rehabilitated Bauxite Mines with Reference to Their Use as Indicators of Restoration Success. Society, 35(1), 161-182.
13. Mueller, U. G., Schultz, T. R., Currie, C. R., Adams, R. M. M., & Malloch, D. (2001). The Origin of the Attine Ant-Fungus Mutualism. The Quarterly Review of Biology,, 76(2), 169-197.
14. Nakamura, A., Proctor, H., & Catterall, C. P. (2003). Using soil and litter arthropods to assess the state of rainforest restoration. Ecological Management and Restoration, 4(s1), S20-S28. doi: 10.1046/j.1442-8903.4.s.3.x.
15. Summerville, K. S., Ritter, L. M., & Crist, T. O. (2004). Forest moth taxa as indicators of lepidopteran richness and habitat disturbance: a preliminary assessment. Biological Conservation, 116(1), 9–18. Elsevier.
16. Uehara-Prado, M., & Freitas, A. V. L. (2009). The effect of rainforest fragmentation on species diversity and mimicry ring composition of ithomiine butterflies. Insect Conservation and Diversity, 2(1), 23-28. doi: 10.1111/j.1752-4598.2008.00025.x.



Steven Crane is a Stanford senior majoring in Human Biology with a concentration in the Psychology and Philosophy of Successful Aging. Beyond an incredible quarter in Australia where he studied ants and moths in the rain forest, Steven loves Stanford life and all it has to offer, especially classes addressing happiness, ethics, and the study of that which makes life worthwhile. Who can really say what the future will bring? For now, Steven's thriving in an off-campus co-op, Ithaka, and looking forward to Burning Man 2011.

License to kill or license to thrill? The *James Bond* movies and twentieth century propaganda films

Harley Sugarman

For almost half a century, MGM's *James Bond* films have captured the hearts and imaginations of a global audience. However, as the series grew into one of Hollywood's most successful franchises, the content of the movies themselves began to drift away from the gritty realism found in Ian Fleming's novels of the 1950s. This study explores the reasons behind such a paradigm shift and reveals similarities between many of the 007 movies and propaganda films produced by the infamous authoritarian regimes of the 20th century. Famous early examples of propaganda cinema, such as Sergei Eisenstein's *Battleship Potemkin*, refined the art of moviemaking and demonstrated film's ability to further the sociological ends of repressive governments. The *Bond* films represent a fascinating compromise that highlights the underlying exchange of cinematic techniques between the movie moguls in Hollywood, and the state-sponsored propaganda machines from both extremes of the political spectrum.

"The name's Bond. James Bond" ranks among the most famous movie lines of all time, and yet despite Bond's iconic status, it is difficult to imagine that Ian Fleming would have recognized the repurposed, indestructible "super-spy" that appeared in many of the Bond films as the same character he created for his series of novels.[1]

This paper will explore the relationship between certain iconic Hollywood movies produced since the advent of film in the 1920s and the propaganda films sponsored and screened by some of the most infamous autocratic governments of the twentieth century. To illustrate this link, it is necessary to first explore the origins of propaganda and the attraction of the moving image to its proponents. This essay will highlight the personalities behind the production of propaganda in both the elected and unelected governments of the pre- and post-World War II periods, and parallel their motives with the rise of the Hollywood studio's "movie moguls," many of whom had escaped from these repressive regimes. As the cultural political and sociological backdrop of American thoughts and fears evolved over time, so too did the US film industry, inflating the propaganda inherent in the James Bond franchise by pitting the hero against whatever political bogeyman captivated the American populace at the time.

What is propoganda and how is it used in film?

The idea of disinformation was originally discussed over two throusand years ago by the Indian political theorist Chanakya in his treatise, the *Arthashastra.* Chanakya wrote about the merits of "silent warfare,"[2] in which astrologers "should fill [the king's] side with enthusiasm by proclaiming his omniscience and association with divine agencies, and should fill the enemy's side with terror."[3] Since then, propaganda has evolved rapidly in its form, but its function remains the same: to manipulate the thoughts of a group of people by spreading information and misinformation. In the past thousand years, as art grew rapidly in popularity and prominence, so did visualized propaganda: the invention of the printing press paved the way for a golden age of posters and pamphlets.

However, perhaps the most significant leap forward for propaganda came with the introduction of cinema into the mainstream at the beginning of the twentieth century. Movies tell a story in a way that posters and books simply cannot, and they are able to envelop the viewer in a world so completely that he can quickly lose all sense of self and become entirely attached to the character on the screen. Concealing the fact that the audience was being manipulated in this way was the key to a successful propaganda film: the moviegoers should identify with the hero on a personal level and naturally empathize with his or her plight.

The establishment of the studio system in 1930s America encouraged directors to create films for the purpose of building a loyal following to the studio as a whole. As each film served as only a single example of the studio's larger offerings, directors used their films to showcase their directors, budget, and stars, just as the dictators used films to showcase themselves, their policies, and their armies. The stunning visuals and large scales of films such as *Gone with the Wind* and *The Wizard of Oz* illustrate the tactics these directors used to attract loyal audiences.[4] Even Joseph Goebbels, Hitler's Reich Minister of Propaganda, envied "the appeal of the Hollywood model, of films designed to distract and entertain while at the same time offering a mass audience appealing images of heroism, leadership, and authority."[5]

One of the most important aspects of the propaganda films, typified by German films such as *Triumph of the Will* and Hollywood's 1977 Bond film *The Spy Who Loved Me*, was portraying the hero's nation in an overly positive light. The Nazi propaganda masterpiece *Triumph of the Will* depicts the Third Reich as a powerful, near-utopian society, juxtaposing towering lines of soldiers with perfect Aryan families and crowds of flag-waving admirers, leaving the audience no doubt about the strength and unity of the German nation.

The Spy Who Loved Me, while subtler in its approach, still displayed a calculated design by directors to inspire love for Britain. Its opening sequence shows Roger Moore's Bond bedding a covert Russian spy, before he is chased on skis through the Austrian Alps by three assassins. After disposing of one of his pursuers, Bond mocks the others as he skis off a sheer ledge thousands of feet high and pulls the cord on his parachute, which opens to reveal a huge Union Jack flag in all its glory. This is in turn saluted by Carly Simon's theme song for the movie, *Nobody Does It Better*.[6] Since only a few of these elements came from Ian Fleming's book, the movie showed a shift in focus toward greater patriotism – and stronger propaganda.

Propaganda and the James Bond franchise

The James Bond brand has become one of the most popular and enduring cultural phenomena of the past half-century. Ian Fleming's twelve novels and two short stories spawned a multi-billion dollar movie franchise - one of the longest running in history - and provided some of the most memorable characters and quotes to ever appear on the silver screen.[7] By continually adapting Ian Fleming's novels into movies that touched on cultural concerns of the time, combined with the use of propagandistic tactics, the Bond franchise was able to capture the imagination of the West.

Having shopped their first 007 project, *Dr No*, around Hollywood studios and distributors for over a year, producers Albert "Cubby" Broccoli and Harry Salzman finally raised the $1 million production budget from one of Hollywood's oldest studios, United Artists (which was acquired by Louis Meyer and Sam Goldwyn's MGM studios shortly thereafter).[8] Although *Dr. No* achieved relatively impressive box office receipts, the team's strategy for their second Bond film (based on Fleming's fifth novel in the series) paved the way for the enormous popularity the franchise came to enjoy.[9]

Escaping the persecution of Eastern Europe during the early twentieth century had left Meyer and Goldwyn with little sympathy for the Communist ideology of the Soviet Union. Similarly, in the 1950s, Americans had been bombarded with anti-Communist "Reds under the Bed" propaganda and the McCarthy hearings, which drove many prominent filmmakers out of Hollywood and fed the prevailing culture of paranoia.

The low point was reached during the Cuban Missile Crisis of 1962, when the relationship between the USSR and the US was strained almost to breaking point. This meant that the 1963 release of *From Russia With Love* could not have come at a better time. The film demonstrated all the traits of a quintessential propaganda movie. Bond (played by Sean Connery) was the idealistic Cold War hero - a quietly charming, classically handsome English gentleman, whose self-assuredness and serious patriotism struck precisely the right chord with western audiences.

Connery's Bond appealed to both men and women, while the Soviets appeared as ruthless but flawed enemies, under the guise of the counterintelligence agency known as SMERSH (an acronym of two Russian words loosely translated as "Death to Spies"),[10] a representation of the KGB. In fact, the Soviets are depicted as so underhanded that they use the fairer sex to do their dirty work: either the beautiful Tatiana Romanova (played by Daniela Bianchi), or the sinister Rosa Klebb (Lotte Lenya).[11] Klebb is an ex-SMERSH agent working for the evil SPECTRE organization that is intent on initiating a nuclear war between the USSR and Britain.[12] The film remorselessly capitalizes on the anti-Soviet sentiment of the age and played a significant role in reinforcing the western media's depiction of the "evil Communist empire" waiting to pounce on any weakness or division shown by the US or its allies.

Given the commercial motivation that was driving the Bond production team, it is hardly surprising that its writers and directors found it necessary to contemporize Bond's on-screen persona, even if it meant a significant departure from the character portrayed by Ian Fleming in his novels. Fleming's 007 is a rough-handed, ruthlessly tough ex-Navy Commander who appeals to the reader through his chauvinism and rugged charm.[13] Broccoli's Bond is a witty, debonair naval officer who uses his natural good looks and understated professionalism to seduce women and outwit his enemies. The film Bond plays it ruthless but fair, and never refrains from offering a sarcastic one-liner to his hapless foe as he delivers the final *coup de grâce*.

Ian Fleming wrote his novels in the early 1950's, immediately after serving as a Commander in the Royal Naval Volunteer Reserve (the very same rank and station as his fictional hero).[14] While Fleming's books present the reader with a relatively authentic world of espionage fashioned by the post-war austerity of the 1950's, movie producers knew that updating and adapting the character and plots would bring the movies more commercial success.[15] Since Fleming did not anticipate the 'space race' between the US and the Soviet Union during the 1960s, the novel *You Only Live Twice* makes no reference to space travel. However, the United Artists' movie of the same name released in 1967 revolves around the devious plans of SPECTRE agent, Ernst Blofeld (one of actor Donald Pleasance's most memorable roles) to "space-jack" one of America's manned rockets.[16] The subliminal message that Russians cannot be trusted to compete fairly tied in neatly with the consciousness of an increasingly media-dependent Western audience. At the same time, the film also included scores of Asian ninja-warriors who helped Bond overcome a common enemy. Once again, this twist to the Fleming original might be overlooked unless it is viewed in the context of the Vietnam War, which had by then become the main point of contention between the US, which was supporting the South Vietnamese, and the USSR, who supported the communists in the north.

Later Bond films featured other departures from the central themes of Ian Fleming's novels, through which the producers sought to introduce their own commentary on the issues of the day. These additions included the increased trafficking of narcotics (*Live and Let Die*), and the risks of a powerful media giant controlling newspapers, television and online content (Elliot Carver (Jonathan Pryce) as a thinly disguised Rupert Murdoch in *Tomorrow Never Dies*).[17] Broccoli and his Hollywood partners never missed an opportunity to capitalize on or shape public opinion, using Bond to deliver the message in both a compelling and entertaining way.

Following the end of the Cold War, the Bond franchise had to adapt to find a new cultural bogeyman in order to remain relevant. Sure enough, they found it in 1993 when a small group of extremists executed the first large-scale terrorist attack on American soil by attempting to detonate a bomb in the World Trade Center.[18] The explosion failed to bring down the building, but caused six casualties and hundreds of injuries.[19] Soon terrorism, not previously considered an everyday issue in the West, burst into the public consciousness. Terms like "jihad" and "suicide bomber" found their way first into common parlance and then into James Bond films.

The 1999 film *The World is Not Enough* opens with the detonation of a suitcase bomb inside MI6 headquarters.[20] Bond pursues the bomber across the River Thames during a lengthy boat chase, and the two find themselves stranded in a helium balloon floating above the Millennium Dome in the heart of London. Once again, patriotism was the order of the day, and Bond's intervention and eventual defeat of the terrorists echoed the defiance that would later become a feature of public opinion in the days that followed 9/11.

Conclusion

So where does that leave James Bond in his role as one of cinema's most iconic and enduring heroes of the past fifty years? Perhaps Ian Fleming anticipated the way his character could be twisted to suit different purposes – inside the story or outside. In an interview published after his death in December 1964, he said:

> *"I don't think that he [James Bond] is necessarily a good guy or a bad guy. Who is? He's got his vices and very few perceptible virtues except patriotism and courage, which are probably not virtues anyway […] I quite agree that he's not a person of much social attractiveness. But then, I didn't intend for him to be a particularly likeable person. He's a cipher, a blunt instrument in the hands of the government."*

In both his on-screen and off-screen personas, Bond is a ruthless secret agent, prepared (and licensed) to kill for the love of his country; his single-mindedness and almost super-human capabilities endow him with an air of invincibility. James Bond cannot be killed - and his timeless appeal has provided Hollywood with the perfect antidote against the spread of Communism, religious fundamentalism, and any other threat posed by the perceived enemies of the West.

References

1. American Film Institute. "100 Greatest Quotes in Movies - AFI." Greatest Films - The Best Movies in Cinematic History. June 2005. Web. 23 Nov. 2010. <http://www.filmsite.org/afi100quotes.html>.
2. Boesche, Roger. "Moderate Machiavelli? Contrasting The Prince with the Arthashastra of Kautilya." Critical Horizons (Brill Academic Publishers) 3.2 (2002): 253-276. Academic Search Premier. EBSCO. Web. 23 Nov. 2010.
3. Kautalya, and T.N. Ramaswamy. Essentials of Indian Statecraft: Kautilya's Arthrasastra for Contemporary Readers. New York: Asia Pub. House, 1962.
4. Kelly, Dennis P. "When The Movies Played Downtown: The Exhibition System of the San Francisco Theater Row, 1945-1970." Journal of Film & Video 54.2/3 (2002): 71-89. Academic Search Premier. EBSCO. Web. 24 Nov. 2010.
5. Ibid.
6. The Spy Who Loved Me. Dir. Lewis Gilbert. Perf. Roger Moore. MGM. 1977. DVD.
7. "100 Greatest Quotes in Movies"
8. Ibid.
9. "Dr. No (1962) - IMDb." The Internet Movie Database (IMDb). Web. 28 Nov. 2010. <http://www.imdb.com/title/tt0055928/>.
10. "SMERSH - James Bond Wiki." The Ultimate James Bond Resource - James Bond Wiki. 7 Dec. 2009. Web. 26 Nov. 2010. <http://www.jamesbondwiki.com/page/SMERSH>.
11. From Russia With Love. Dir. Terence Young. Perf. Sean Connery. MGM, 1963. DVD.
12. Ibid.
13. Fleming, Ian. You Only Live Twice. [New York]: New American Library, 1964.
14. Pearson, John. The Life of Ian Fleming. New York: McGraw-Hill, 1966.
15. Fleming, Ian. Quantum of Solace: the Complete James Bond Short Stories. London: Penguin Books, 2008.
16. "You Only Live Twice"
17. "Tomorrow Never Dies (1997) - IMDb." The Internet Movie Database (IMDb). Web. 28 Nov. 2010. <http://www.imdb.com/title/tt0120347/>.
18. McCarthy, Andrew C. "When Jihad Came to America. (Cover story)." Commentary 125.3 (2008): 26-31. Academic Search Premier. EBSCO. Web. 26 Nov. 2010.
19. Ibid.
20. The World Is Not Enough. Dir. Michael Apted. Perf. Pierce Brosnan. MGM, 1999. DVD.
21. "The Playboy Interview: Ian Fleming." Playboy Dec. 1964. Web. <http://www.hmss.com/lagniappe/PlayboyInterview_IanFleming_1964.txt>.

Harley Sugarman is a freshman living in Santa Barbara, California. He grew up in London, where he first became acquainted with the world of James Bond. He is currently undecided about his major, but is considering a degree in Computer Science, with a minor in Film Studies. Harley is a member of the Magic Castle in Hollywood and, in his spare time, also enjoys producing and directing short films, playing tennis and ultimate frisbee, and listening to almost any rock music produced in the '70s.

Rearranging Durkheim: An anthropologically ethical take on a classic theory of religion

Maggie Sachs

Many theories of religion tend toward a naturalistic, sociological, Durkheimian framework. While these theories have pointed out important dimensions of religious experience, they risk reducing the human experience of religion to a purely social or psychological phenomenon, without taking seriously the claims of religious adherents themselves. How can we begin to work toward a unique theory of religion, which incorporates both the social causes of religion (per Durkheim) while allowing for a much more sensitive and ethical hermeneutic of religious experience? This paper expands and revises Durkheim's theory of religion toward a more malleable approach to the ethnographic study of religious communities and the subjective experiences of individuals within them. My theory is motivated by an attempt to use Durkheim's theory in the discipline of anthropology to inform the ways in which anthropologists go about fieldwork and ethnographic writing when it pertains to the study of religion.

Many theories of religion tend toward a naturalistic, sociological, Durkheimian framework. While these theories have pointed out important dimensions of religious experience, they risk reducing the human experience of religion to a purely social or psychological phenomenon, without taking seriously the claims of religious adherents themselves. J. Samuel Preus's *Explaining Religion: Criticism and Theory from Bodin to Freud* presents an explanatory framework for the study of religion by introducing and analyzing influential theorists of religion on an evolutionary trajectory up to the present day. Throughout his book, Preus favors theorists like David Hume and Émile Durkheim for their naturalistic approaches to religion. Conversely, John H. Hick's *An Interpretation of Religion: Human Responses to the Transcendent* assesses the validity of a naturalistic worldview as opposed to a religious worldview—ultimately claiming that since "the universe is religiously ambiguous" it is reasonable for individuals to experience it either religiously or naturalistically (12). Using these two texts as a starting point, how can we begin to work toward a unique theory of religion which incorporates both the social causes of religion (per Durkheim) while allowing for a much more sensitive and ethical hermeneutic of religious experience? How can we expand and revise Durkheim's theory of religion toward a more malleable approach to the ethnographic study of religious communities and the subjective experiences of individuals within them? My theory is motivated by an attempt to use Durkheim's theory in the discipline of anthropology to inform the ways in which anthropologists go about fieldwork and ethnographic writing when it pertains to the study of religion.

Instead of positing that the focus of religion is something other than the transcendent (as does Durkheim), this paper proposes an alternate ending to Durkheim's theory, in which there remains a possibility that what devotees claim to be worshiping ultimately exists. In this paper, I posit two dimensions of religious experience: (1) External, community support and commonality in belief, which compel one to worship in a specific, ritualized way, along-side others, and (2) Internal, spiritual feelings which compel one to search for higher truth. The former ensures the reproduction of religion throughout history, and the latter is what maintains religion's steady heartbeat within the individual. These layers interlock and overlap to create religious meaning for communities and individuals, and are understood in varying degrees by each religious person.

Taking these dimensions of religious experience into account, my revisionary theory of religion is presented in layers as well. The first layer of my theory shows the degree to which religion is built through the community, and religious beliefs are predicated on communal values (per Durkheim). The second layer shows how religious life may embody something highly meaningful to devotees, given individual experiences that are distinct from the social. I argue that the social and ethical principles of communal life are what people celebrate and observe in worship, although feelings generated through this worship can be understood as the manifestation of something Real, felt and affirmed through personal experience. Durkheim's theory need not finitely label the object of its attention. In fact, cultural anthropology historically has taken issue with Durkheim's methods including his quantitative, scientific collection of "social facts" through objective techniques.

A "Durk-Hickian" View of Religion

First, Durkheim's theory of religion posits that religious experience and belief can only be understood as something created by humans themselves. He assumes the preliminary spark of religion to be the "positing of an 'ideal world'" (Preus 173). This world is on a plane above the believer's profane existence. On this idealized plane, there exists a "moral power upon which he depends and from which he receives all that is best in himself" (174). This sentiment is borne and sustained through communal worship, wherein individuals succumb to the "obligatory" moral power of the group, setting aside their individualistic motivations (Durkheim 205). In its most elementary form, Durkheim's hypothesis claims, "The states of perpetual dependence in which we find ourselves in the face of society inspires in us a feeling of religious awe…[it] originates not in individual feelings but in collective states of mind, and that it varies according to these states" (206). Durkheim only acknowledges the individual in terms of his behavior as a member of a group.

Durkheim, according to Hick's definition, was a non-realist; Hick understood religious belief and ritual as responses to an ontological Real (Hick 172). Hick provides a critique of Durkheim when he weighs the validity of "The Naturalistic Option" as a view of the universe. However, Hick criticizes

Durkheim on the basis of Durkheim's vast generalizations about religion, not on the basis of his "non-realist" perspective. While early in Hick's book it becomes clear that he is not interested in signing on with a particular naturalistic approach to religion, he claims that, "even when [naturalistic, speculative analyses of religion emerge] unconvincing, they can nevertheless be seen as correctly indicating the presence of elements of human projection and cultural conditioning within the various forms of religious experience" (266). Hick thinks human projection is mostly pervasive within the major post-axial religions.

According to Hick, projection occurs because "all awareness, whether of our more immediate or of our more ultimate environment, is accordingly formed in terms of conceptual systems embodied in the language of particular societies and traditions" (173). To experience the Real as it is means to attain a non-worldly state. Thus, Hick posits that "we can therefore only experience the Real as its presence affects our distinctively human modes of consciousness" (173). The "critical realism" he advocates "takes full account of the subjective contribution to all awareness," whereas "naïve realism" does not fully acknowledge the "interpretive element of sense perception" (173). Hick perfers critical realism because its interpretive aspect allows for the preservation of "cognitive freedom" in understanding the transcendent reality. He contrasts realist theories with those non-realist theories that do not take religious language seriously.

Interestingly, Hick's critical realist approach does not seem largely incompatible with Durkheim's non-realist approach. The two approaches could easily be taken together to move toward an understanding of the same basic principles of religious belief. Hick describes how the literal-minded Christian can still achieve verification of true religion in the afterlife, although his eschatological visions while on earth were not precise (180). Here, a concrete picture of the afterlife helps individuals to connect with the Real. Conversly, Durkheim asserts that any person who posits a transcendent realm to explain religious feelings is entirely mistaken; religious adherents entirely worship the moral power of society, but call it something different, thus they are wrong about the object of their worship. Here, some other state is sought through the worship of a worldly moral power. Thus, both Hick and Durkheim suggest that conceptions of the transcendent are produced through the worldly imagination.

The Union of Two Religious "Layers" Defines the "Religious"

I have proposed that there exist two layers of religious experience: social and spiritual. Durkheim seems to address only the first of these layers as truly possible. However, his theory might well be expanded to allow for another, second layer of religious experience. One cannot ignore the role of religion as a social institution, or even as an instrument of social reproduction. For example, it is common practice for children to adopt their parents' religious beliefs and practices without feeling much, if any, religious conviction. But then, what makes religious identity any different from another sort of identity? A soteriological criterion, drawn from Hick, will function as a qualifier for religion. By this explanation, one may be religious by believing in the presence of some transcendent essence and its salvific properties, without having a self-proclaimed, definite religion or religious identity.

Religious world-view and religious identity should be assessed as two different things. On the one hand, a *religious view of the universe* requires that one has belief in a non-human essence, lying beyond human faculties, the alignment with which will promote salvific transformation.[1] On the other hand, a *religious identity*, I argue, is an inherited title given at birth, carrying with it a set of common rituals, and a degree of social capital. One may identify with a religion by using its name, practicing its rituals, and coming together with those who share the given identity. One may either chose to accept or reject the identity on the basis of individual experience. While religious identity is, for the most part, a signifier of a person's religious conviction, there are cases in which the two are incongruent. In such cases, religious identity is absent and a religious view of the universe is present, or *vice versa*. Let us not ignore these cases, for they are important indicators of what religion means for different people.

On the Existence and Persistence of Religion

Accepting Birth-Given Religion Without Question: A "Paradox of Doxa"

In *Masculine Domination*, Bourdieu presents the following questions: How can we understand the historical reproduction of order in social relations, especially gender relations? How may we talk materially and symbolically about such relations? And what keeps people from acting out against social norms? To tackle these issues, Bourdieu introduces the concept of a *paradox of doxa*. Here, *doxa* refers to a community's taken-for-granted rules of social relations, or "one-way streets and…no-entry signs" (Bourdieu 1), and the *paradox* refers to individuals' consistent compliance with that doxa without question or "transgression" (1). *Habitus,* then, is what Bourdieu presents as the catalyst for this historical reproduction of social relations; it is a set of bodily enactments, adopted through education and "early upbringing" (27), which actively perpetuate doxa on the individual level—in other words, "The antagonistic principles of [the] identity are…laid down in the form of permanent stances, gaits and postures which are the realization, or rather the 'naturalization' of an ethic" (27). In order, then, to discuss the ways in which *doxa* is signaled within communities, and the potential harm these signals may incur, Bourdieu proposes the concept of *symbolic violence*, which refers to a class of signals and systems, visible in everyday life, which perpetuate hegemonic constructions, symbolizing the inferiority of a particular group. He describes this violence as "a gentle violence, imperceptible and invisible even to its victims" (11) which may be unconsciously internalized by individuals, further naturalizing the *doxa* inherent to social order.

It would seem that this theory could well be adapted to fit a theory of religious persistence. Religion may be defined for a community as a standardized system of beliefs, rules, and rituals, the practice of which may determine one's standing in a religious society. Thus, the pressures of *doxa, habitus*, and *symbolic violence* all act on individuals to recapitulate the *doxa*, making it more and more difficult to transgress an institutionalized religion as time wears on. Birth-given religion becomes a *doxa* of sorts, the rituals become the *habitus,* which solidifies the *doxa,* and *symbolic violence* becomes the rhetoric of inferiority toward other known faiths, which makes it further difficult to transgress and eventually override the *doxa*.

On the Ease of Transmission

But then comes the question: *Why does*

religion transmit through generations as easily as the transmission of, for example, gender roles? First, the early exposure of children to religious stories, myths and rituals may account for the ease of transmitting religious beliefs and identities through generations. Even if the religious ideologies and rituals are not explicit, they can be inherited through continual observation of the religious *habitus* of others as one is growing up. In this sense, inheriting gender roles, inheriting language, and inheriting religion are all functionally similar processes. Second, it seems that a religious interpretation of the universe stems from an innate human desire to know more than what is given by the five senses, and to bring higher meaning to the human experience. According to Hick, the myth is an exceedingly important element of religion, as it is able to deal with "traditional mysteries" such as "Where do we come from and what are we here for?" (Hick 356). In non-esoteric terms, myths can aid in orientation toward the Real, while "assuaging our anxiety in the face of the deep mystery of our existence" (356). For some, faith in having solved this mystery provides the solidarity necessary to live out their lives. Furthermore, if those around you, especially your social superiors (like parents and grandparents), seem to have the answer, it may be more difficult to question their convictions. Thus, religion flows easily down through generations and persists.

The Dynamic Nature of Religion: Durkheim as One Half of the Cycle of Perpetuation

However, within the framework of Bourdieu's theory as it applies to religion, it is indeed also the case that religions can, and do, change with time. Durkheim offers an interesting perspective on the dynamic nature of religion. In positing this inextricable link between religion and the nature of communal action, Durkheim has given a compelling answer to the question: *What explains the essentially universal persistence of religion among humans?* (Preus). Preus states in the closing of his chapter on Durkheim: "Durkheim has provided a powerful answer to the question of why religion has survived: it is a reality interlocked with society itself. Not only does society generate it, but society depends upon religion for its own renewal" (176). While compelling, the theory also seems somewhat incomplete. Hick is skeptical of the outright and all-pervasive applicability of Durkheim's theory, for "it presumes a religiously homogenous and unified state of society… [and] presupposes the human condition before the emergence of the autonomous individual exercising a moral and intellectual judgment which may diverge from that of a society as a whole" (117).

While the recurrence of religion appears to be a cyclical process, Durkheim's theory only considers half of the cycle. One must consider the second layer of religion—the layer in which soteriological, eschatological, experiential and spiritual conceptions of religion, as they enter human consciousness, become a part of the religious experience. Durkheim's theory does very little to cope with the experiences and claims of the religious adept. Providing Durkheim's theory with a way to understand individual religious experience within his sociological framework is quite a difficult task indeed, but one that must be grappled with.

If one allows for Durkheim's half of the cycle (that society creates religion), one is left with a theory which begs to be completed. A more complete view would be one in which religious experiences of "spiritually impressive" individuals (Hick 301), when stated outright (whether predicated on the encounter with, discovery of, or invention of the divine realm) may elicit a band of followers, which again make it their object to worship the moral power of this new communal system. Durkheim's view, with this revision, is thus uprooted from its severely limited scope. This allows religion, as it is perpetuated throughout history, to look dynamic rather than static. The endless loop that I describe allows for a chicken-or-the-egg effect in which one might imagine a purely sociological initial cause for religion, out of which religious adepts later bloomed—or a singular person first becoming orientated toward a religious understanding of the universe by means of individual experience, into which a community of spiritual followers was later drafted.

Parnngurr, Western Australia: Considering the Views of Durkheim's Ethnographic Subjects with Regard to His Theory

It may, now, be helpful to understand the actual place from which Durkheim drew his theory. Recently I was fortunate to spend time in Parnngurr, Western Australia, which coincidentally happens to be home to some of the Aboriginal groups that constituted the focus of Durkheim's analyses of totemism. The people with whom I had primary interaction self-identified as "Martu." The ritual, as well as the mundane, day-to-day activities for Martu—which constitute law, order, "moral imperatives," kinship obligations and communal solidarity—are understood as "The Dreaming." In its most basic sense, The Dreaming is a body of mythology, which describes the creation of the landscape and the law by ancestral spirits.

Through the upholding of a common moral code, The Dreaming is perpetuated. In this sense, Bourdieu's theory of *doxa* and *habitus* can be applied. Children grow up understanding what land to burn, how to act appropriately toward others, given their "skin group," their "Dreaming" or totem, and the ways to forage for food. But it is through a rigorous process of initiation that one earns rights to tell certain myths embodied in The Dreaming. Undergoing this highly ritualized, esoteric process of initiation is simply something that most do not question. Following initiation, a member of society has the responsibility to "hold," possess ownership of, and maintain certain Dreamings. Maintenance of Dreamings occurs through processes of land maintenance, and through the process of telling one's own Dreaming stories. There is an inherent expectation within the society that The Dreaming, through maintenance of its many components, will be eternally preserved for coming generations (Myers 53).

How Durkheim's Theory Functions for His Subjects of Study

Even approaching a critical discussion, let alone analysis, of The Dreaming would be nearly impossible without spending a large part of one's life living with Martu, or being initiated into the totemic system. However, Fred Myers, renowned for his lengthy ethnographic work in this region, may speak with some degree of authority. Here, he comments on the all-pervasive nature of The Dreaming, which makes it exceedingly difficult to define: "Because it touches so many dimensions of [Martu] life, The Dreaming…possesses no single or finite significance…We understand the social meaning of such a construct only when we are able to relate it to the particular circumstances of those who use it" (47). But what can we make of this idea

of construction? The Martu certainly do not believe that they constructed it themselves. They claim that "The Dreaming…is not a product of human subjectivity or will" (53). It is just something that exists, and is to be obeyed as the "Law."

One could say that The Dreaming and its meaning for individuals is constructed through processes of socialization. Individuals experience The Dreaming as a present reality, through ritual (138). The Dreaming, however, should not be simply understood as a human construction, but may be understood in the critical realist sense as a series of myths predicated on an attempt to understand a transcendent noumenal reality. Given the "cognitive"[2] nature of Martu language with regard to the Real, it is hard to imagine Martu conceding that the stories of The Dreaming are predicated on nothing more than the human-made moral principles of the society, or that the rituals do not correspond to a transcendent reality.

Thus, Durkheim's subjects of study might have opposed his theoretical claims (given the theory's non-realist conception of human religious action). However, something like a critical realist theory—in which one posits a connection to a noumenal Real through a set of mundane and sacred rituals taking place in the human realm, and adherence to a set of moral codes in day-to-day life—may provide a more charitable and internally acceptable interpretation of Aboriginal religion. While it is entirely possible for a religious adherent to understand and accept social elements of worship, my multi-layer approach entails the consideration of a second, spiritual layer of understanding. Those who consider themselves religious must hold this second layer, which posits the existence of a noumenal Real through a set of human experiences. In this theorized second layer, profoundly individual spiritual experiences may occur, and religious life may come to embody something highly spiritually meaningful to such devotees. It is in the application of these two layers in various thicknesses to an individual's understanding of the universe, that a religious interpretation of the universe emerges—an interpretation that is different for every individual.

Conclusion: What Positing a Second Layer Adds to a Field Study

My revision of Durkheim's thoery acknowledges an added religious layer of meaning; it allows for a more fruitful and personal discourse between the cultural insider and the outsider. In practice this consequently leads to a more complete and less personally biased, ethnographic representation of religion and religious experiences.

To further emphasize the efficacy for a dual-layer approach, let us now consider what could hypothetically be gained by applying the "second layer" understanding to the aforementioned case and others like it, instead of relying on Durkheim's purely naturalist approach. This theory of religion may be more practical, more nuanced, and less objective than Durkheim's in a fieldwork scenario, and would strive to understand the rituals, ceremonies and beliefs from the native's point of view. It is not simply that the theory will provide a more "charitable" reading of religion to the believer, but that in such a charity, the ethnographic observer may be open to a wider range of ways to understand a particular set of practices and beliefs during fieldwork. This may also result in a more dynamic and nuanced presentation of the ethnographic material when written up. By understanding religion as something both social and possibly transcendent, one may orient oneself toward religious beliefs without falling back on staunch biases, which undermine the very statements of the ethnographic subjects, and limit the potential depth of conversations between cultures.

Additionally, an understanding of the proposed theory of religion would likely garner a more subjective rhetorical style in its presentation than any writing of Durkheim. Thus, an ethnographic exploration which propounds this theory will not only be attentive to cultural religious practices, but will dually attend to questions of individual understandings of religion and testaments of profoundly religious experiences. This is what Durkheim's writing leaves out. Such a method will take into account the varying levels and types of belief, through sentiments of individuals within the tradition of interest. In *Culture and Truth,* Renato Rosaldo claims that a comprehensive view of a culture cannot be gleaned from a detached perspective; one must remain sensitive to changes in cultures over time, and the internal diversity of cultures. Durkheim, in *The Laws of Sociological Method,* is not interested in collecting personal stories. His aim is to create a map of the social body as objectively as possible. For Durkheim, then, the informant never appears; the subject is turned into a number, a part of the statistical whole. Proposing more focus on particular events, personal narratives, and case histories in anthropological research, Rosaldo pushes us away from detached observation and its corresponding Durkheimian rhetoric.

Thus, the theory I have presented yields a methodology that considers the nuances in its subjects' understandings of a particular religious tradition, while providing more credible insights for analysis than methods of distanced observation and general, objective cultural reports. Indeed, this theory also recognizes that the two layers of religious construction and meaning function on a gradient for individuals, and cannot be conflated into a single objective truth. A theory of religion must allow the ethnographer to sensitively respond to, and seek to shed light on, the comments of ethnographic subjects, and other cultural aspects of *imponderabilia.*[3] These are the pieces missing from a Durkheimian approach, which does not ask these questions. While Durkheim provides a sound hypothesis for the "first layer" social causes of religion, he concludes that there is no possible second layer. For Durkheim, there is no potential for the existence of a transcendent realm. The theory espoused in this paper is far more malleable than a staunch naturalist approach, in that it takes seriously the religious claims of its human subjects and leaves them open for analysis and discussion, while still allowing the explanations set forth by Durkheim and Bourdieu to help account for the perpetuation and persistence of religion in society.

Notes

1.For example, Hick's soteriological criterion for religion

2. Term borrowed from John Hick's *An Interpretation of Religion*

3. A term coined by Bronislaw Malinowski in his *Argonauts of the Western Pacific* to refer to the facets of everyday life which defy immediate understanding

References

1. Bourdieu, Pierre. *Masculine Domination,* translated by Richard Nice. Stanford: Stanford University Press, 2001.

2. Durkheim, Émile. *Concerning the Definition of Religious Phenomenon*. In "Seeing the Sacred with the Social Eye: Émile Durkheim's 'Religious Sociology.'" In Thinking About Religion: A Reader, edited by Ivan Strenski. New York: Blackwell Publishing, 2006.

3. Durkheim, Émile. *The Laws of Sociological Method*. Edited by George E. Catlin. Translated by John H. Mueller and Sarah A. Solovay. 8th ed. New York: Free Press, 1966.

4. Flood, Josephine. *The Original Australians: Story of the Aboriginal People.* Crows Nest NSW, Australia: Allen and Unwin, 2006.

5. Hick, John. *An Interpretation of Religion: Human Responses to the Transcendent*. 2nd ed. New Haven: Yale University Press, 2004.

6. Myers, Fred R. Pintupi Country, *Pintupi Self: Sentiment, Place, and Politics among Western Desert Aborigines.* 1986. Reprint, Berkeley: University of California Press, 1991.

7. Preus, J. Samuel. *Explaining Religion: Criticism and Theory from Bodin to Freud.* New Haven: Yale University Press, 1987.

8. Rosaldo, Renato. Culture and Truth: *The Remaking of Social Analysis*. Boston: Beacon Press, 1993.

Maggie Sachs is a senior co-terming in religious studies and majoring in anthropology, and is a member of the Stanford women's lacrosse team. Last summer she traveled to Nizamuddin Auliya Sufi shrine in Delhi, India to undertake fieldwork for her honors thesis on the ways in which people living and working in Nizamuddin are responding to the changing landscape of the city and the urban development projects occurring there. Maggie is particularly interested in incorporating anthropological methods into the study of Islam and Islamic communities around the globe, and aspires to attend graduate school in anthropology in the future.

Effects of natural porous additives on the tensile mechanical performance and moisture absorption behavior of PHBV-based composites for construction

Anthony Alvarado, Kristhian Morales, W. Srubar, S. Billington

Bio-based composites manufactured from hemp fiber and PHB polymers or PHBV copolymers have similar mechanical properties to wood and have the potential to be used in structural applications. Previous research shows that fiber-reinforced composites surpass the strength of plywood in both flexure and shear, and their flexural modulus is 45% to 75% that of structural lumber. PHBV-bone meal and PHBV-pumice composites were developed with the intent of reducing density and price of PHBV matrices in these hemp fiber composites. Methods of manufacturing and testing are discussed; mechanical properties, diffusivity, and biodegradation behavior of the composite specimens are compared to those of pure PHBV. Tensile tests reveal that the composites are stiffer and more brittle than PHBV, experiencing almost no plastic deformation. The Fickian diffusion model is used to analyze moisture uptake and to calculate the average diffusion coefficient of the composite and pure PHBV specimens. Diffusivity tests revealed that the moisture absorption rate in the bone meal composite was twice that of PHBV. While the moisture content of the pure PHBV and pumice composite specimens is less than 1% of their weight, the pumice composite absorbs moisture at a faster rate.

Research has shown that materials derived from poly(β-hydroxybutyrate) (PHB), a naturally occurring biopolymer, and its copolymers such as PHB-co-poly(β-hydroxyvalerate) (PHBV), can be used to engineer lightweight bio-based composite materials that exhibit mechanical properties comparable to those of wood and wood-plastic products presently used in construction [1]. However, the density of these materials is twice that of dimensional lumber, adversely affecting ease of constructability, material efficiency, and energy embodied in material transport. The purpose of the research presented herein was to manufacture PHBV-based composites with lower costs and densities while obtaining mechanical property and water absorption behavior similar to those of wood and wood plastic composites (WPC). It was important to determine that the mechanical properties were comparable to those of wood and WPCs because these composites are to serve the same purpose as these materials in constructions. Equally, the water absorption behavior of the composites was monitored to predict their performance when exposed to water, as they would be in practice under different types of weather.

Pumice and bone meal were selected as two natural aggregates for this preliminary study. Pumice, a highly porous, low-density volcanic rock, is widely used in the construction industry for production of lightweight concrete and low-density breeze blocks [2]. Pumice is domestically produced and is cost effective in large quantities ($0.37/lb) [3] compared to PHBV ($2.24/lb retail price). Bone meal is also a very porous, low-density, inexpensive food-waste byproduct material ($1.33/lb retail price). We considered both of these aggregates to be good candidates for creating lightweight PHBV-based composites that would not affect the biodegradability of the resultant material.

This paper details the development of PHBV/pumice (PHBV-P) and PHBV/bone meal (PHBV-BM) composites for structural purposes. Also presenting the observed mechanical performance and moisture absorption behavior of the composites in comparison to those of the pure PHBV samples.

1. Methodology

1.1 Materials and Processing

Pelletized PHBV was supplied by Tianan Biological Material Company, Ltd. Ground pumice stone and ground bone meal were obtained from DK Hardware, Inc. and The Espoma Company, respectively. A sieve analysis was conducted using sieves #16, 20, 100, and 200 on both ground additives to ensure a maximum particle size less than 1mm, as required for thin film extrusion processing. Figures 1 and 2 show that bone meal particles were, in general, larger than those of pumice under the 1mm threshold since 85% of the particles used in this sample were larger than 147μm in size. The bone meal underwent chloroform dissolution pre-treatment to remove any dissolvable particulates. The pumice and bone meal were subsequently oven-dried overnight at 66°C to remove all moisture from the aggregates and to prevent superheated water vapor from creating voids in the composite strips during extrusion.

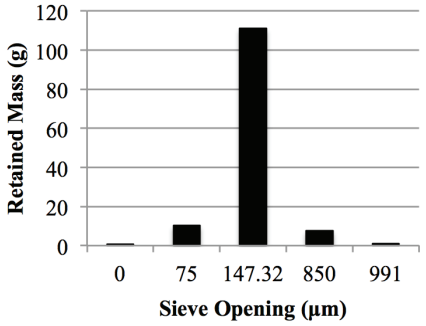


Fig. 1 Bone meal particle gradation curve.

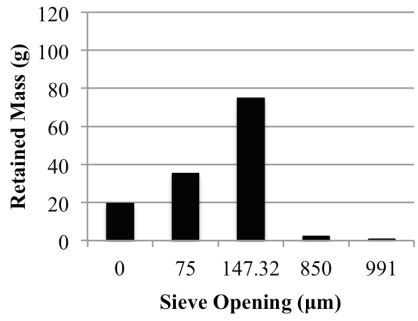


Fig. 2 Pumice gradation curve.

1.2 Manufacturing

PHBV-P and PHBV-BM composite films were extruded using an ATR Plasti-Corder extruder with four heating zones set at temperatures of 150, 160, 160, and 150°C. A 10:1 weight ratio of PHBV and additive were simultaneously hand-fed into the main hopper. This ratio was selected in order to compare the data obtained from this research with the results of a simultaneous project investigating the same properties for composites that are 10% wood fiber by weight. The extruder, equipped first with a 3mm rod dye, produced thin rods of composite that were pelletized and re-extruded into thin strips. This two-phase extrusion process was designed to adequately mix the PHBV and bone meal and to ensure a uniform distribution of filler material. The manufacture of pure PHBV specimens required no pre-pelletizing since the PHBV was supplied in a pelletized form.

In order to optimize the quality and uniformity of the composite, three extruded ribbon strips were stacked, placed between aluminum plates, and hot pressed together at 180°C for 70 seconds under 0.5 tons of force. Chloroform dissolution tests confirmed the weight fraction of the bone meal and pumice composites to be 9.13% bone meal and 12.8% pumice, respectively.

1.3 Mechanical Testing

All dog bone samples were manufactured according to ASTM Standard D638. Twenty samples were manufactured, sized, and tested (3 PHBV, 10 PHBV-P, and 7 PHBV-BM). The composites specimens were tested in tension according to ASTM Standard D638, using a 15-kN MTS 858 Table Top System. After failure, the specimens were removed from the MTS and photographed in the failure region using a Nikon SMZ800 microscope, as seen in Figure 4.

1.4 Moisture Absorption Testing

Nine discs (three of each material) were cut from the composite plates for the water absorption experiment setup outlined in ASTM Standard D5229. Each disc measured 2 inches in diameter. Before immersion, the specimens were placed in an oven at 66°C for 21 hours in order to remove any absorbed ambient moisture. After preconditioning, the average oven-dry mass, thickness, and diameter of the specimens were recorded for each composite specimen set and used as a basis for comparison for the remainder of the experiment. The discs were submerged in water at room temperature (22° C) in 500 ml Pyrex Glass containers. It was assumed that diffusion occurs solely through the top and bottom of the disc since this area is very large relative to the surface area of the edges. In order to increase the amount of surface exposed to the water, the discs were placed on an aluminum wire rack.

Resulting stress-strain data obtained from the tension test performed on the pure PHBV, PHBV-BM, and PHBV-P specimens is shown in Figure 3. The specimen stiffness, yield and ultimate strengths, as well as yield and ultimate strains (elongation to break) were calculated based on the experimental data. The summary of the obtained material properties is shown in Table 1.

PHBV, PHBV-P, and PHBV-BM exhibited very similar stiffness and yield strengths. Figure 3 shows that they have nearly identical elastic regions, with very similar slopes. It is important to note that the elastic modulus for PHBV-P shows a 12.35% increase over that of pure PHBV, which is attributed to pumice having a higher stiffness than PHBV (4.65 GPa vs. 2.90 GPa) [4-5]. The specimens containing bone meal did not show a statistically significant change in modulus.

Although all three materials elastically deform in a comparable manner, PHBV shows a much more ductile response than PHBV-P and PHBV-BM which display very little plastic deformation prior to fracture. The reason for the brittleness in the PHBV-P and PHBV-BM

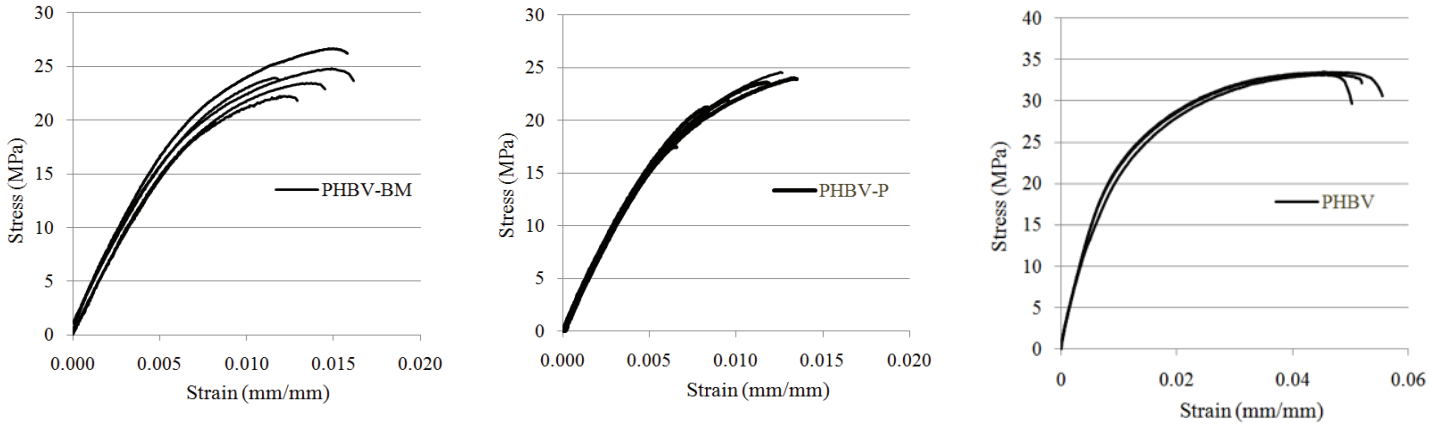


Fig. 3 Comparison curves of tensile behavior between bone meal, pumice, and PHBV specimens.

Specimen	Yield Strain (mm/mm)	Yield Stress (MPa)	Elastic Modulus (GPa)	Ultimate Stress (MPa)	Ultimate Strain (mm/mm)
PHBV	0.00597	16.51	2.87	33.55	0.0558
PHBV-BM	0.00492	15.27	3.15	23.41	0.0136
PHBV-P	0.00463	14.37	3.30	22.18	0.0105

Table 1 Uniaxial tension material properties summary for PHBV, PHBV-BM and PHBV-P.

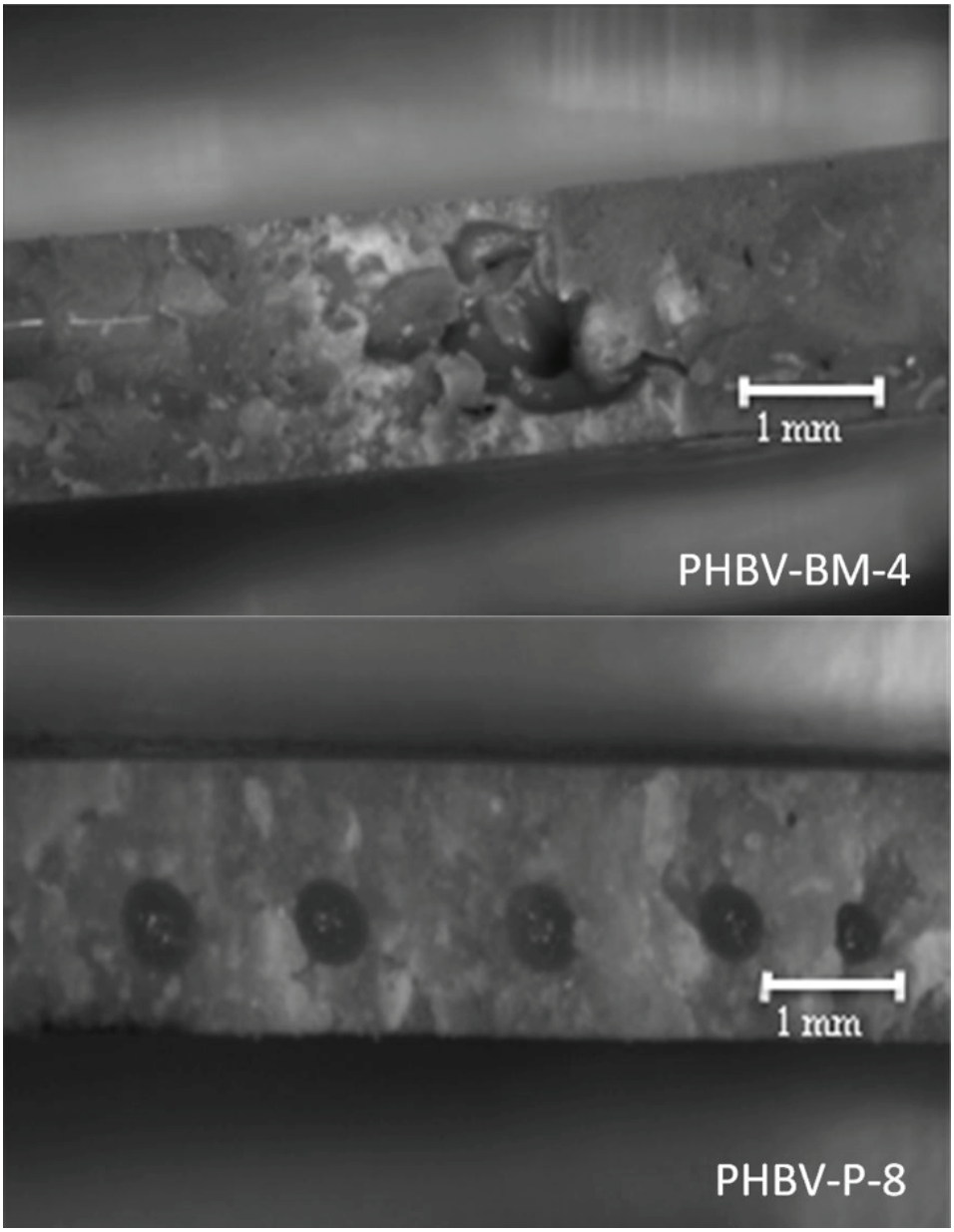


Fig. 4 Optical microscopy images of voids at fracture region in PHBV-BM-4 and PHBV-P-5 specimens.

composites is that the addition of small particulates exacerbates the crystallization of the PHBV polymer during processing and leads to embrittlement. Furthermore, the introduction of aggregate particles in PHBV matrix might lead to the creation of defects in the composite where cracks form due to localized stress concentrations, which causes the composite to resist plastic deformation. Other contributing factors to the decreased ductility and tensile strength are defects produced during the manufacturing of the specimens. After the tensile testing was conducted, microscopy of the broken dog bone samples revealed that in some cases the specimens fractured where voids caused by air bubbles were present (Figure 4). Thus, the window between the oven-drying pre-treatment and the onset of extrusion must be carefully managed in future manufacturing processes.

The rule of mixtures model was used to predict the elastic modulus of the PHBV-P composite. Given the elastic modulus of the matrix, E_m = 2.90 GPa, and the elastic modulus of the filler, E_f = 4.65 GPa, the following equation was used to calculate the theoretical elastic modulus for the composite, E_c,

$$E_c = v_f E_f + (1 - v_f) E_m$$

where v_f is the volume fraction of pumice in the composite (%). In order to obtain this volume fraction, the following equation was used:

$$v_f = \frac{w_f/\rho_f}{w_f/\rho_f + (1-w_f)/\rho_m}$$

where w_f is the weight fraction of filler in the composite, P_f is the density of the filler (0.72 g/cm3), and P_m is the density of the matrix (1.25g/cm3). The volume fraction of pumice in the PHBV-P composite was determined to be 20.23%.

Using this value, the rule of mixtures predicted E_c to be 3.25 GPa, which was 1.5% lower than the average modulus seen in the empirical data (3.30 GPa), and well within a standard deviation of that value. Since the data seems a good fit for this model, it is inferred that the interfacial bond between PHVB and pumice is very good, causing the deformation of both matrix and filler to be the same under longitudinal loading (isostrain).

In the case of the PHBV-BM specimens the theoretical elastic modulus for the composite material, E_c, calculated from the rule of mixtures overestimates the experimentally derived elastic modulus by 34.6%. Thus the bone meal composite cannot be accurately described by this model. Possible reasons behind the discrepancies between the theoretical and experimental model are listed below.

1. Weak interfacial bond between the polymer and bone particles:

The rule of mixtures model assumes a good interfacial bond between the matrix and the filler material and that the deformation of the particles and the matrix is the same (isostrain conditions). We performed calculations assuming isostress conditions by using:

$$E_c = \frac{E_m E_{bone}}{(1-v_{bone}E_{bone} + (v_{bone})E_m}$$

with E_c = 3.09. Since it falls within one standard deviation of the experimentally derived elastic modulus, it is considered statistically equivalent. Thus it can be concluded that the material behaves like large-particle composite materials and there is a weak bond between the bone meal and the matrix.

2. Variability in published values for bone meal:

The density of chicken bone varies significantly depending on the age of the chicken [6]. Different values for density yield different results for E_c.

2.2 Moisture Absorption Test Results

Figure 5 shows a plot of moisture absorption as a function of √t for pure PHBV,

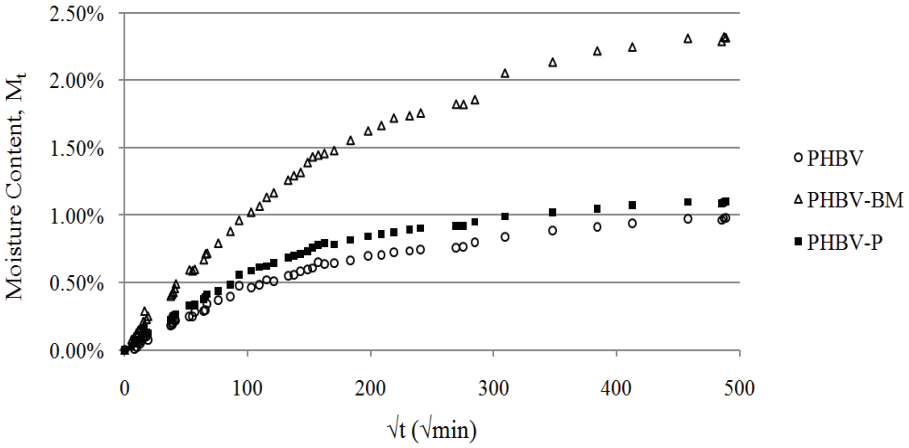


Fig. 5 Moisture absorption behavior of PHBV and bone meal composite.

PHBV-BM, and PHBV-P composite specimens.

In accordance with the Fickian diffusion model, moisture absorption (M_t) of the composite specimens increases linearly with √t., prior to the composite reaching equilibrium. The diffusion coefficients, D_{sorp}, for all specimens were derived by using the methods outlined by Wang, *et al* [7]. D_{sorp} was calculated using the slope of the linear portion of the moisture absorption curve and the saturation value, M_∞, using:

$$D_{sorp} = \frac{\pi}{4} M_\infty^{-2} l^2 \theta^2$$

where M_∞ is the saturation value, l is one half of the disc thickness (m), and θ is the slope of the linear region of the moisture absorption curve. Table 2 summarizes the diffusion coefficients for the three materials.

The diffusion coefficients show that the water absorption rate for the bone meal composite is greater than that of pure PHBV and pumice composite specimens. Pure PHBV and pumice composite absorbed the least amount of water at maximums, reaching maximums of 0.986% and 1.107% moisture by weight; however, it should be noted that the pumice composites absorb water at a faster but comparable rate to the pure PHBV discs. Low moisture uptake for the pure PHBV specimens is expected because of the hydrophobic nature of the polymer. The bone meal composite's higher moisture content, about 2.3 times more than PHBV and PHBV-P, is largely due to the weak interfacial adhesion between the coarse bone meal and the polymer matrix. Gaps between the polymer and bone meal allow water particles to travel through the material at a faster rate. The hot-pressing methods used to manufacture these specimens do not ensure a polymer surface coating around the composite; therefore, voids between the matrix and bone meal particles may exist on the surface of each specimen. These voids may provide pathways through which water molecules may enter, and thus increase the degree of moisture absorption. Since the bond between the matrix and pumice particles was stronger than that between the matrix and bone meal, the number of voids in PHBV-P was fewer. The reason that PHBV-P absorbed more water than PHBV was due to the porous nature of pumice, which increases the space that water molecules can occupy within the material.

Specimen	D_{sorp} $(10^{-13})(m^2/s)$
PHBV	1.091
PHBV-P	1.498
PHBV-BM	1.502

Table 2 Diffusion coefficients of PHBV, PHBV-P, and PHBV-BM composites.

Figure 6 shows the thickness swelling behavior for the three materials. Due to PHBV's hydrophobic nature, it is difficult for moisture to enter the polymer and cause the material to swell. The change in thickness for PHBV remains below 1%; therefore, it can be considered negligible regardless of fluctuations. For bone meal composites, however, there is a rapid increasing in swelling within the first 500 hours, followed by fluctuations between 1% and 1.5%. While it is not clear whether the bone meal itself is expanding due to moisture absorption, the interaction between the bone meal particles, polymer chains, and water molecules can be the reason behind the swelling. The pumice composite behaves similar to PHBV with regards to thickness swelling in that it remains below 1%. This amount of swelling can be considered negligible as it is much lower than the maximum allowed swelling (<11%) in current industry materials and is similar to that found in other studies with wood-plastic composites [8-9]. The greater variability in the data differentiates the pumice composite and pure PHBV material, but manufacturing defects may cause this variability. Given the porosity of the pumice, the lack of thickness swelling is expected since water can be stored inside the discs without causing significant changes in the dimensions of the particulate filler.

No significant radial expansion was observed in any of the three materials as can be seen in Figure 7. In all cases, the materials seem to stabilize after 1000 hours of immersion and remain under 0.5%.

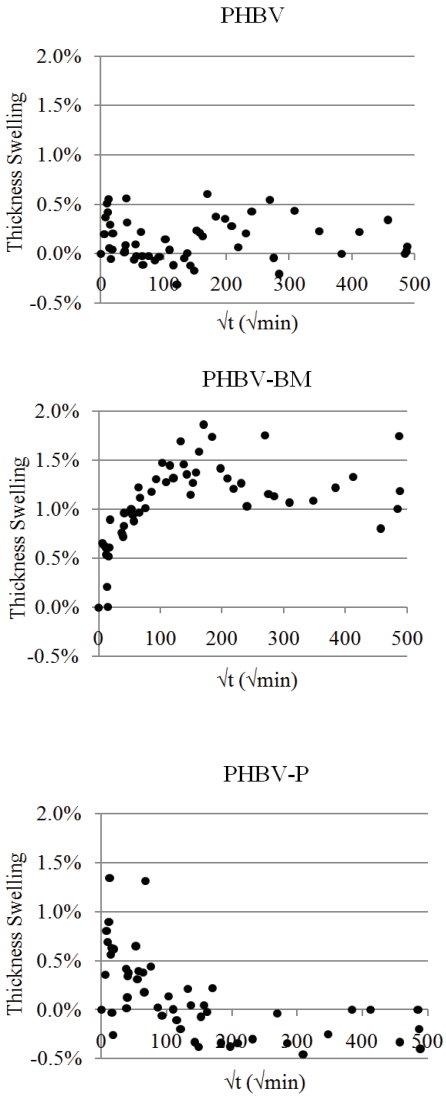


Fig. 6 Thickness swelling behavior of PHBV, PHBV-P, and PHBV-BM.

However, this amount of radial expansion is small and can be disregarded.

3. Conclusion

In order to evaluate the effects of using bone meal and pumice as fillers in PHBV, the mechanical properties and water uptake behavior of these composites was compared to those of pure PHBV. A two-phase extrusion process was employed to uniformly distribute the filler material.

Mechanical testing revealed that the PHBV-P composite has an elastic modulus that is 12.35% higher than that of PHBV. However, both bone meal and pumice composites are more brittle, undergoing little plastic deformation prior to fracture. The agreement between the empirical data and the theoretical results derived from the rule of mixtures model suggests that the interfacial bond between the pumice and PHBV was strong when uniaxial loads were applied. The opposite was substantiated for the bone meal specimens.

The Fickian diffusion model was used to predict preliminary diffusion coefficients in order to describe the water uptake behavior of the bone meal and pumice composites. Bone meal absorbed a maximum of 2.32%, the highest value amongst the three materials. Neither PHBV-P nor PHBV showed significant thickness swelling or radial expansion.

Mechanistically, bone meal and pumice composites behaved similarly to pure PHBV up to the yield point. This bodes well for construction applications such as formwork and decking where the composite material may be exposed to external loading. Eventually, it is expected that this material will replace wood in both structural and non-structural applications without the worry of dry rot and high levels of moisture attack. Once this material has surpassed its useful life, it will reduce waste-load in landfills caused by the slow degradation process of wood. In addition to waste-load reduction, bio-based composites require less energy to produce, as they can be degraded in an anaerobic environment to produce methane, which can be fed back to PHB-producing microbes or used as an energy source [10-12]. In order to make this self-sustaining material more competitive with dimensional lumber, this research aims to reduce cost and density of current PHBV-based materials by replacing a percentage of PHBV with less expensive filler materials, which would make the transition towards bio-based composite materials less economically straining.

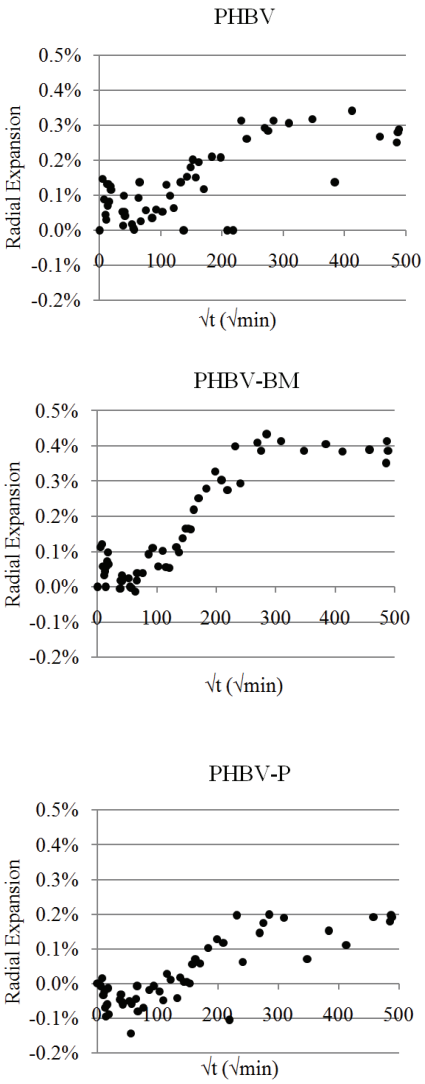


Fig. 7 Radial expansion of PHBV, PHBV-P, and PHBV-BM.

4. Future Research

In order to ensure a more uniform mix between the PHBV and bone meal filler and reduce problem of thickness and air bubbles, injection molding of specimens could be substituted for current hot-pressing manufacturing methods. The polymer-rich surface layer which injection provides may reduce moisture absorption rates. Future research could also focus on finding the optimum weight fraction of bone meal or pumice filler that will yield the best mechanical testing results.

5. Acknowledgements

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References

[1] Christian SJ, Billington SL. Mechanical Characterization and Structural Assessment of Biocomposites for Construction. Civil and Environmental Engineering. Stanford, CA: Stanford University; 2009. p. 219.
[2] Crangle, R.C. Pumice and Pumicite. US Geological Survey Minerals Yearbook 2009; 591-596.
[3] Crangle, R.C. Pumice and Pumicite. US Geological Survey, Mineral Commodity Summ. 2010
[4] Kurugol, S.K., Tanacan, L.T., & Ersoy, H.Y.E. Young's modulus of fiber-reinforced and polymer-modified concrete composites. Construction and Building Materials, 2008; 22:1019-1029.
[5] Sultana, N.S., & Wang, M.W. Fabrication of HA/PHBV composite scaffolds throughthe emulsion freezing/freeze-drying process and characterization of the scaffolds. J Mater Sci: Mater Med 2008; 19:2555-2561
[6] Sanger, V. L., Holt, J. A. Bone Density and Ash Studies in Avian Osteopetrosis. Avian Dis 1982, 26:177-181.
[7] Wang, W., Sain, M., Cooper, P. A. Study of Moisture Absorption in Natural Fiber Plastic Composites. Composites Sci and Technol 2005; 66:379-386.
[8] Stiles, Surface & Panel Buyer's Guide. 2010. http://www.pbmdf.com/cpa30/files/ccLibraryFiles/Filename/ 000000001750/Buyers-Guide-2010-Part-2.pdf
[9] Kamel, M.A. Investigating the mechanical and physical properties of wood plastic Composites (WPC). 2010.
[10] Billington SL, Criddle CS, Frank CW, Morse MC, Christian SJ, Pieja AJ. Bacterial poly (hydroxy alkanoate) polymer and natural fiber composites. In: Publication USPA, editor. U.S.; 2008. p. 9.
[11] Morse MC. Anaerobic biodegradation of biocomposites for the building industry. Civil and Environmental Engineering. Stanford: Stanford; 2009. p. 110.
[12] Criddle CS, Pieja AJ. Use of selection pressures to enable microbial biosynthesis of polyhydroxyalkanoates from anaerobic degradation products. In: Publication USPA, editor. U.S.; 2009. p. 12.
[13] Reich, T., Gefen, A. Effect of Trabecular Bone Loss on Cortical Strain Rate During Impact in an In Vitro Model of Avian Femur. Biomed Eng OnLine 2006; DOI: 10.1186/1475-925X-5-45, www.biomedical-engineering-online.com/content/5/1/45

Anthony Alvarado is a junior majoring in Civil Engineering with a Structural Engineering focus. His academic interests include studying methods to engineer sustainable construction materials, bridge rehabilitation and design, and the ability of a structure to impact community and spatial identity. He hopes to continue his research on bio-based composites and pursue advanced studies in structural engineering. In his spare time, he enjoys mentoring middle school students and introducing them to the engineering design process, spending time outdoors, hiking, and drawing.

Kristhian Morales is a junior majoring in Civil and Environmental Engineering with a concentration in Structures and Construction. His academic interests include structural analysis and design, computer modeling, American literature, and foreign languages. He hopes to continue his involvement with research in the structural engineering field and plans to obtain master's degree in Structural Engineering and Geomechanics. He is an officer of the Stanford Society of Chicano/Latino Engineers and Scientists and enjoys reading and watching films in his free time.

Predicting and understanding bronchopulmonary dysplasia in premature infants

Laney Kuenzel

Bronchopulmonary dysplasia (BPD) is a serious but poorly understood lung disorder affecting premature infants. In this work, we use machine learning techniques to characterize the physiological signals (*e.g.*, heart rate, breathing rate) of infants with BPD. We identify physiology that often precedes clinical interventions for BPD and laboratory measurements known to be predictive of BPD, and create a physiology-based classifier for BPD with strong performance on our data set. Such a classifier could easily be adopted by a hospital, allowing doctors to gauge an infant's BPD risk using only noninvasive measurements already recorded for all infants. We also discuss several findings of medical interest concerning particular features—including signal frequency content and inter-signal correlation—with predictive value for BPD.

Bronchopulmonary dysplasia (BPD) is a lung disorder that affects infants, primarily those born prematurely. Defined as the requirement for oxygen therapy for at least 28 postnatal days, BPD occurs in nearly a third of infants with birth weight under 1000 grams [1]. BPD is associated with far-reaching negative consequences such as further respiratory problems, cerebral palsy, and cognitive impairment [2].

Unfortunately, BPD is one of the most poorly understood complications of prematurity. In particular, there is no consensus on the pathogenesis of the disease. Among the commonly hypothesized causes of BPD are ventilator-induced injury, lung immaturity, lung inflammation due to infection, and genetic predisposition [2,3].

Previous work on predicting BPD has focused primarily on correlating eventual BPD diagnosis with laboratory measurements, medicine administrations, and mechanical ventilator settings. Such studies have consistently shown BPD to be significantly associated with certain abnormal blood gas levels (*e.g.*, low blood pH) as well as aggressive ventilation [4-6].

Despite the abundance of studies seeking to identify factors associated with BPD diagnosis, a large gap still exists in the body of literature on BPD prediction: very little is known about what characterizes the physiological signals (such as heart rate and respiratory rate) of infants eventually diagnosed with BPD. We believe that this area is under-explored largely because it has only recently become possible to obtain fine-grained physiological time series data for hospitalized infants. We were fortunate enough to have access to this type of data, enabling us to conduct novel research on the relationship between physiological signals and BPD. This endeavor was particularly exciting due to its potential to generate important new medical knowledge.

In our search for physiological signatures for BPD, we focused specifically on three signals: heart rate, respiratory rate, and oxygen saturation (a measure of the amount of oxygen carried by the blood). We had two main reasons for choosing these particular signals.

First, it makes sense from a biological perspective that lung problems would manifest in these three signals. The lungs serve to introduce oxygen from inhaled air into the bloodstream and to release carbon dioxide from the blood as exhaled air. Therefore, we would expect infants with poor lung function to exhibit low oxygen levels (motivating our use of the oxygen saturation signal) and high carbon dioxide levels. Furthermore, in infants with lung problems, we would expect to observe altered patterns in the breathing rate and heart rate (motivating our use of the respiratory rate and heart rate signals) as the body attempts to respond to the blood gas imbalance by adjusting the amount of air entering and exiting as well as the speed with which the blood is circulating.

Second, these three signals are recorded noninvasively for every infant in a standard neonatal intensive care unit (NICU). Consequently, a predictive model for BPD based only on features of these three signals could easily be adopted by any NICU. This is not the case for a model with features that rely on more invasive, expensive, or nonstandard measurements.

For these reasons, we formulated our overall objective: to understand whether and how BPD manifests in an infant's heart rate, respiratory rate, and oxygen saturation level. More concretely, our goal was to construct a predictive model for BPD based on these three physiological signals.

I. Motivation and Real-World Applications

Before describing our efforts to create a predictive model, we first discuss how such a model would be useful in the real world. Suppose we had a model that could accurately predict BPD based on physiological signals alone. By examining how the model makes its predictions, we could identify the common characteristics of infants eventually diagnosed with BPD. This would constitute a valuable contribution to our currently limited understanding of the disease's pathophysiology. Insight into the emergence and evolution of BPD, as well as its effect on an infant's body systems, would help doctors and researchers find effective ways to treat and prevent the disease.

Yoder *et al*. [6] point out another important application of predictive models for BPD: study design. Many therapies have been proposed to prevent BPD, and some of them may have dangerous side effects. If researchers had access to a model that could predict the likelihood of BPD, they could include only those infants with high BPD risk in their studies, thus sparing low-risk infants from unnecessary and potentially dangerous interventions.

Most importantly, a predictive model for BPD could be used by doctors in an NICU setting. As described in the introduction, the heart rate, respiratory rate, and oxygen saturation of each infant in an NICU is continuously monitored. Thus, an NICU could adopt a computational model using this data with no changes to their existing monitoring procedure. Doctors could then use the output of the model to make informed decisions about treatments. As a concrete example, corticosteroids administered shortly after birth can reduce the risk of BPD, but they can also have serious negative effects, such as gastrointestinal bleeding and

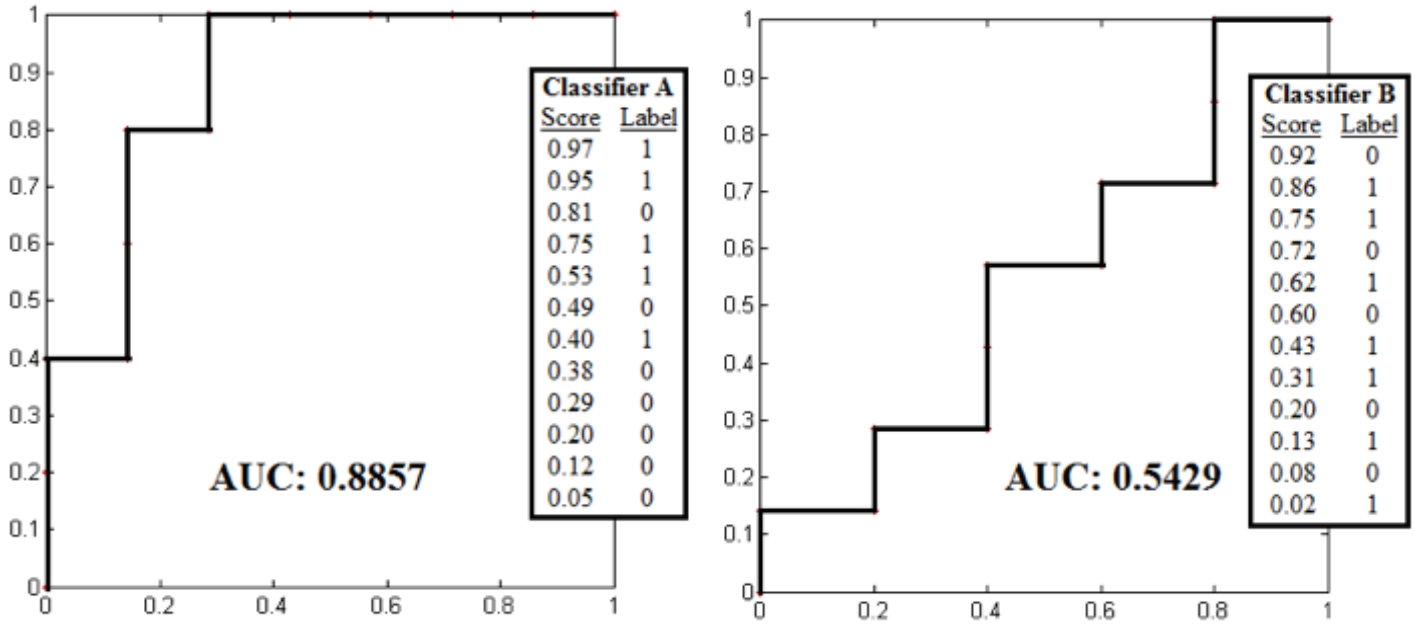

Fig. 1 Two examples of ROC curves for classifiers giving the scores displayed in the tables.

dangerous thickening of the heart muscle [7]. Thus, the decision of whether to administer corticosteroids to a given infant is a very difficult one. With more accurate information about an infant's BPD risk level, doctors would be better able to make the best choice for the infant's long-term health.

These examples demonstrate how a predictive model for BPD could substantially improve the treatment of premature infants. With this motivation in mind, we move on to describe the toolset we used in creating our model.

II. Machine Learning Approach

In our efforts to develop a predictive model for BPD, we used techniques from machine learning, a subfield of artificial intelligence that focuses on computer algorithms that use experience to improve at a specific task. In our case, the task was predicting BPD diagnosis in infants based on physiological signals observed in the first few days of life. We hoped to develop an algorithm which, given data on BPD and non-BPD infants, would learn general rules for predicting BPD in other infants.

We will now define the machine learning concepts and terminology used in the remainder of this paper. Readers already familiar with machine learning can proceed to Section III.

A. Basic Definitions

We refer to data points as *examples*. *Positive examples* refer to those taken from infants with BPD, and *negative examples* refer to those taken from infants without BPD. We say that positive examples have *label 1* and negative examples have *label 0*. A *classifier* is an algorithm that takes an example as input and outputs a binary prediction. During the *training phase*, the algorithm uses labeled data, or *training examples*, to learn prediction rules. During the *testing phase*, the algorithm makes predictions for new examples (*testing examples*) without labels. A "good" classifier is one that makes accurate predictions on the testing examples (*i.e.,* predictions which agree with the true labels).

B. ROC Curve and AUC

To quantify the accuracy of predictions made by a classifier, we use the *receiver operating characteristic (ROC) curve*. Suppose that we have a classifier which, rather than simply outputting a binary prediction for each example, assigns each example a score indicating how likely it is to be positive. To obtain actual predictions from such a classifier, we specify a cutoff score such that all examples with a score above the cutoff are classified as positive and all others are classified as negative. The ROC curve for a score-assigning classifier is a plot of the true positive rate versus the false positive rate for different possible cutoff scores. Figure I shows the ROC curves for two example classifiers.

To obtain a single number summarizing the information in an ROC curve, we measure the area under the curve, or the AUC. The AUC is a meaningful quantity because it gives the probability that, for a randomly chosen positive example and a randomly chosen negative example, the classifier assigns a higher score to the positive example. The AUC of a perfect classifier is 1. A classifier with an AUC of 0.5 is no better than a classifier that assigns random scores to each example.

When we have relatively few examples (as in the current research), a classifier could potentially have a high AUC by chance. To address this issue, we use a quantity called the conservative mean AUC, which penalizes classifiers with performance that varies widely across different subsets of examples [8].

C. Logistic Regression

In this work, we used *logistic regression*, a common and relatively simple classification algorithm. Before explaining logistic regression, let us first define a *hyperplane* in n-dimensional space as an (n-1)-dimensional subspace, possibly translated by some distance from the origin. A hyperplane in two-dimensional space is just a line, and a hyperplane in three-dimensional space is an ordinary plane. Informally, logistic regression attempts to find a hyperplane in the example space that separates the positive examples from the negative examples as fully as possible. During the training phase, the algorithm learns a *weight* corresponding to each input variable. Together, these weights specify a hyperplane.

D. Overfitting

One large challenge in machine learning

is a phenomenon called *overfitting*. Overfitting occurs when a classifier—or more generally, any learning algorithm—learns a prediction rule based not only on the data's underlying patterns but also on the noise present in the training data. The resulting classifier performs poorly on new testing examples because its rules do not generalize well. Figure II illustrates the concept of overfitting.

Overfitting is more likely to occur when the number of training examples is small, since a learning algorithm has less information to use in distinguishing between true patterns and noise in the data. Similarly, high-dimensional data increases the risk of overfitting since there are more ways in which noise can coincidentally look like a pattern to the classifier.

We can often avoid overfitting by transforming raw data into a lower-dimensional representation prior to running it through a learning algorithm. Consider a scenario in which we have a day's worth of minute-interval heart rate and respiratory rate data for each infant in our training set. We could simply provide our algorithm with the raw data values, but overfitting would then likely occur due to the high dimensionality of the data. A better approach would be to calculate the mean heart rate and mean respiratory rate and present these aggregate quantities to our algorithm.

E. Features

In the example above, we would refer to the mean heart rate and mean respiratory rate as *features*. More generally, features are the new variables that result when we transform our data from raw form into another representation. We say that a feature is *informative* or *predictive* with respect to a particular classification task if it helps us distinguish between positive and negative examples. In the case of BPD prediction, we would expect that mean heart rate is probably an informative feature, whereas the number of letters in the infant's last name is most likely not informative.

In logistic regression, the weight learned for a given feature is indicative of how heavily the algorithm relied on that feature to separate the positive and negative examples (with weights high in absolute value corresponding to the most useful features and weights close to zero corresponding to the least useful).

Now that we have provided the necessary background information, we move on to describing our attempt to apply machine learning techniques to predict BPD.

Feature	Full Set	Match Set
Number of dextrose administrations	0.84	0.82
Number of ISTAT blood gas measurements	0.84	0.78
Number of ventilator setting increases	0.82	0.82
Number of ventilator FiO_2 setting increases	0.80	0.79
Number of ventilator rate setting increases	0.77	0.77
Number of 10% dextrose administrations	0.75	0.78
Maximum airway resistance measurement	0.84	0.74
Mean blood pH measurement	0.82	0.74
Minimum blood pH measurement	0.80	0.84
Maximum blood carbon dioxide measurement	0.79	0.84
Range of blood carbon dioxide measurements	0.77	0.78
Range of blood pH measurements	0.74	0.87
Minimum blood oxygen measurement	0.74	0.77
Median RR range over 5-minute windows	0.77	0.77
Mean abs. diff. between consecutive RR values	0.77	0.74

Table 1 Conservative mean AUCs for top features.

III. Selection Criteria

We had access to minute-interval time series data collected from monitoring devices attached to premature infants during their entire stay in Stanford Hospital's NICU. For these infants, we also had data on all of the clinical events—*e.g.*, laboratory tests and ventilator setting changes—that occurred during their hospitalization.

Of the infants admitted to Stanford's NICU between March 2008 and March 2009, we considered those satisfying the following criteria: gestational age $\leq$ 34 weeks, birth weight $\leq$ 2000 grams, length of life $\geq$ 28 days (thus allowing for BPD diagnosis), and availability of $\geq$ 5000 minutes of monitor data. Of these infants, 30 with a positive BPD diagnosis were included in the study. As negative examples, an additional 37 infants were chosen at random from those diagnosed with respiratory distress syndrome, an indicator of breathing problems at the time

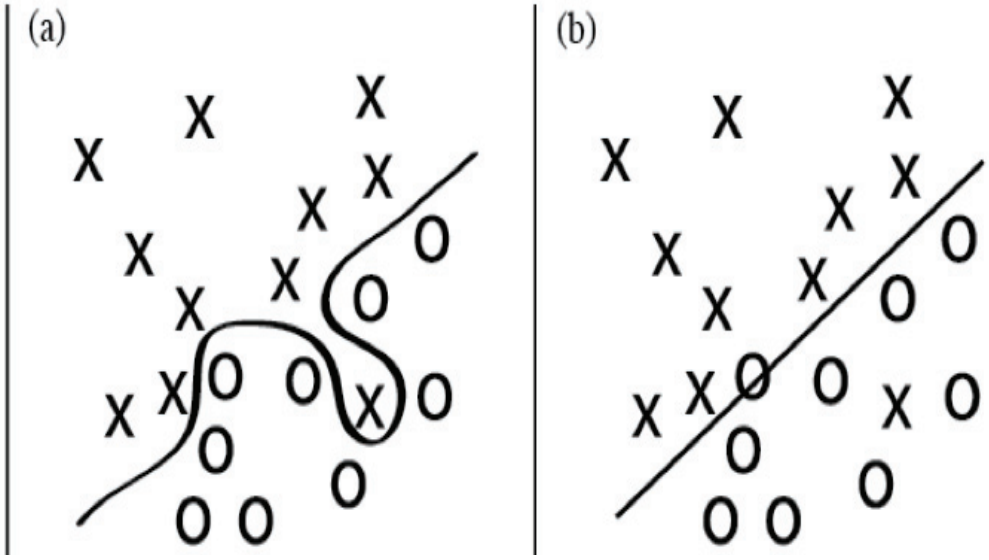

Fig. 2 An illustration of the concept of overfitting. While the boundary in **(a)** successfully separates all positive examples from negative examples, it likely would not generalize to further data as its shape depends highly on the particularities of these data points. The boundary in **(b)** does not perfectly separate the examples, but it seems to give a much better fit to the underlying pattern in the data without capturing the noise.

Intervention Type	Features		
	Non-RBM	RBM	All
Dextrose administration	**0.67**	0.65	0.64
ISTAT blood gas measurement	**0.55**	0.54	0.54
Increase in any ventilator setting	**0.77**	0.72	**0.77**
Increase in ventilator FiO_2 setting	**0.75**	0.70	**0.75**
Increase in ventilator rate setting	0.60	**0.65**	0.62

Table 2 AUCs for PLR Classifiers to predict interventions.

of birth, but not of BPD.

In this set of infants, low gestational age and low birth weight were found to be highly predictive of BPD, with areas under the ROC curve (AUCs) of 0.93 and 0.91, respectively. For this reason, we also created an age/weight-matched set of 20 infants (10 with BPD and 10 controls), for which gestational age and birth weight had much lower AUCs of 0.62 and 0.59, respectively.

IV. Initial Feature Exploration

For each infant, we had a large quantity of data, including several long physiological time series and information on tens of thousands of diverse clinical events. As a first step, we wanted to determine which of the many available pieces of data would be most useful to us for predicting BPD. We drew from the BPD literature, our discussions with Stanford NICU clinicians, and our observations from visualizing the data to identify 160 potentially interesting features of the first 5000 minutes of data available for each infant.

Around forty of these features were functions of the physiological signals, such as mean, range, standard deviation, and amount of time below or above threshold values. Sixty more features were related to laboratory measurements (*e.g.*, platelet count and blood oxygen level) identified in previous studies as predictive of BPD. For each type of measurement, we included as features the first, mean, minimum, and maximum values, the range of values, and the number of measurements taken. We also included about thirty features related to ventilator type and settings. Rounding out the set of features we considered were the numbers of administrations of over twenty types of medicine.

To determine the predictive value of each feature, we computed the conservative mean AUC (with k=10 folds), as proposed by Khosla *et al*., in order to penalize features sensitive to variations in sampling [8]. The fifteen top-performing features across both the full set and the age/weight-matched set are displayed in Table I along with their conservative mean AUCs. We observed that these top features fell into three categories:

(i) Six of the features measured the frequency of various clinical interventions (namely medicine administrations, blood draws, and ventilator adjustments) ordered by the NICU doctors. The strong performance of these intervention frequencies as features suggests that Stanford clinicians have a good sense of which infants are at highest risk for BPD or other complications and therefore require the most treatment and surveillance.

(ii) Seven of the features were functions of measurements other than the physiological signals. More specifically, six were related to blood gas values and the last was a function of the airway resistance measurement, which is taken only for infants on a particular type of ventilator. Interestingly, the frequency of blood draws was generally more predictive of BPD than the actual measurement values resulting from those draws. Assuming that the NICU doctors order more blood draws for the infants that they deem sicker, this result suggests that the doctors' assessment of an infant's health status is richer in predictive information than the blood gas levels for that infant.

(iii) The remaining two features were functions of the respiratory rate. We were surprised to find that, of the over forty physiological features we considered, only these two were among the fifteen most informative overall.

As described in the introduction, our aim in this project was to shed light on the relationship between physiological signals and BPD. We found in this initial exploration that most of the highly predictive features for BPD were directly related not to physiology but instead to intervention frequencies and laboratory measurements. Based on this result, we decided to focus our further efforts on finding physiological proxies for the informative interventions and measurements.

V. Motivation for "Proxy" Approach

Essentially, we decided to examine the relationship between our three physiological signals and the interventions and measurements corresponding to the features in categories (i) and (ii) above. More specifically, we hoped to identify physiological signatures characterizing the time when a given intervention is ordered, in the case of category (i), or the time when an infant has a certain measurement value, in the case of category (ii). Our rationale was that because the intervention frequencies and measurement values were so predictive of BPD, good physiological proxies for them would likely be predictive of BPD as well.

In addition to their potential value in BPD prediction, physiological proxies for the informative features would be useful in several other ways. In the case of category (i), we could use physiological signatures for a given intervention to create a tool for reporting whether an infant is exhibiting physiological signatures that typically precede that intervention. Such a tool would help NICU doctors decide whether and when a certain intervention is necessary.

Physiological proxies for the blood gas and resistance measurements in category (ii) would be valuable for two reasons beyond BPD prediction. First, we could incorporate such proxies into a tool that would let doctors noninvasively obtain a rough estimate of blood gas levels or resistance for an infant. This type of tool would reduce the number of invasive blood draws performed, benefiting both the infant's health and the hospital's budget. Second, independent of any prediction application, an understanding of how abnormal measurements manifest in the physiological signals of premature infants would constitute valuable medical knowledge.

Why did we believe that physiological proxies for our predictive features would exist at all? In terms of interventions, Stanford NICU clinicians informed us that they decide what interventions to order based partly on an infant's physiological signals. For example, doctors often consider low oxygen saturation and high respiratory rate as a sign that the ventilator is not

working effectively and requires setting increases. In terms of measurements, we expected that abnormal blood gas values would be reflected in the physiological signals since the body sets the heart and respiratory rates based on blood levels of oxygen and carbon dioxide.

For the above reasons, we believed that physiological proxies for our informative features were likely to exist. The goal of our subsequent experiments was to identify such proxies so that we could ultimately use them to predict BPD.

VI. Experimental Setup

A. Data

In our first set of experiments, we considered five interventions with predictive frequencies: dextrose administrations, ISTAT blood gas measurements (note that "ISTAT" refers to a type of handheld blood gas meter), and increases in three types of ventilator settings. We examined the 60-minute intervals of our physiological signals preceding these interventions. The intervals were taken from the first 5000 minutes of monitor data available for each of the infants in our set. As negative examples, we wanted to find intervals during which the doctor considered the infant's state and could have ordered the intervention but did not. For this purpose, we chose 60-minute intervals preceding times when the doctor entered electronic comments about the infant but did not order the intervention in question during the hour before or after comment entry. This procedure resulted in sets of 1862, 966, 930, 806, and 146 intervals for the five interventions.

In our second set of experiments, we took the 60-minute intervals prior to measurements of blood pH, blood oxygen, blood carbon dioxide, and airway resistance that occurred during the first 5000 minutes of monitor data for the infants in our set. We had 827, 827, 771, and 189 intervals, respectively, corresponding to these four measurements.

B. Feature Extraction

Based on both visual analysis of the data and the literature on time series feature extraction, we chose five approaches to obtaining features from the physiological signals, resulting in 448 total features. We now describe each of the feature extraction approaches:

(i) We computed simple functions of the signals, such as mean, range, and variability. We believed these functions had promise as features because Saria *et al*. demonstrated them to be predictive of general morbidity in premature infants [9].

(ii) We calculated time-lagged correlation between each pair of signals. We believed that correlation might be informative based on our visualization of the data. Moreover, research on other complications of prematurity shows that sick infants often have impaired autoregulation [10], leading to synchronization of physiological signals.

(iii) We used the discrete Fourier transform (DFT) to obtain features capturing the frequency content of each signal. In essence, the Fourier transform allows us to characterize the variability in the signals at different time scales, and previous studies suggest that heart rate variability is a meaningful indicator of infant health [11].

(iv) We applied the Time Series Topic Model (TSTM) developed by Saria *et al*. [12]. The TSTM segments the physiological signal into regions ("words") generated by the same autoregressive process, indicating similar short-term dynamics. The TSTM also learns higher-level "topics" corresponding to different distributions over words. As features, we used both word and topic frequencies obtained from the TSTM.

(v) We learned a two-layer belief network using the sparse Restricted Boltzmann Machine (RBM) algorithm proposed by Lee *et al*. [13]. A single example consisted of the sixty values each of heart rate, respiratory rate, and oxygen saturation that occurred during one 60-minute interval. We pre-processed the data by applying PCA whitening and then learned a sparse RBM model with 400 hidden units. With the resulting hidden unit probabilities, we trained a second sparse RBM layer with 400 hidden units. As features for a given interval, we used the inferred values of the second-layer hidden units resulting from feeding the interval's signals forward through the trained model.

We normalized each feature to have mean zero and unit standard deviation so that the weights learned by classifiers would be meaningful in comparison to one another.

C. Predicting Interventions

For each of the five interventions, we trained a penalized logistic regression (PLR) classifier using the algorithm proposed by Zhu and Hastie, which introduces a quadratic regularization term to penalize high weights [14]. On a training set consisting of 70% of the intervals, we performed five-fold cross-validation to select the optimal regularization parameter. More specifically, for each of a range of possible parameter values and for each fold, we computed the AUC of the ROC curve for the classifier's outputted probabilities. Using the parameter that maximized the conservative mean AUC over the folds, we trained a PLR classifier on the entire training set and then used this classifier to make predictions on our test set.

We repeated this procedure three times: once with all 448 of our features, once with only the 400 RBM features (*i.e.*, those of type (v) in Section VI-B), and once with only the 48 non-RBM features. We separated the features in this way because we were especially interested in comparing the belief networks with our other feature extraction methods, in terms of how effectively they captured the information in the physiological signals. The resulting AUCs are reported in Table II and will be discussed in Section VII.

D. Predicting Measurement Values

We first tried linear regression to predict measurement values but found that the amount of error was unacceptably high for each measurement type. We instead decided to attempt the simpler task of predicting whether the values fell above or below a given threshold. We observed that NICU doctors often mentally represent an infant's blood gas values with ternary ("high", "normal", or "low") or binary

	Features		
Measurement Type	Non-RBM	RBM	All
Blood pH	0.86	0.76	**0.87**
Blood oxygen	**0.74**	0.58	0.68
Blood carbon dioxide	0.69	0.68	**0.72**
Airway resistance	**0.72**	0.56	0.65

Table 3 AUCs for PLR Classifiers to predict measurements.

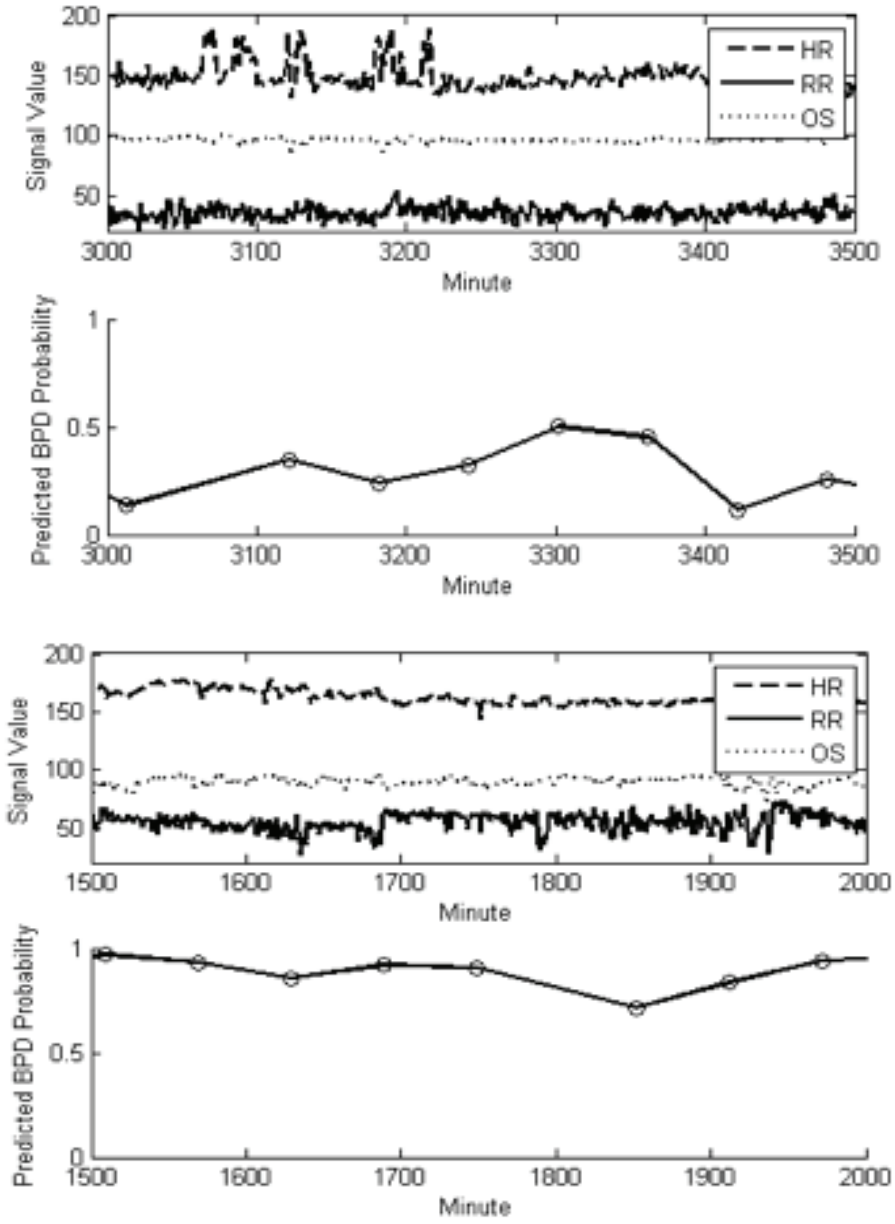

Fig. 3 The outputs of the interval-based BPD classifier for two infants, one without BPD (top) and one with BPD (bottom). The upper panels show the physiological signals for the infants, and the lower panels show the predicted BPD probabilities over time.

("abnormal" or "normal") values. Thus, we reasoned that a model which made binary predictions of measurement value would be useful to NICU doctors.

As thresholds separating "low" from "high" for blood pH, oxygen, and carbon dioxide, we used values indicated as clinically meaningful by Stanford physicians. For airway resistance, since such a value was not available, we took the ROC curve generated for the "maximum resistance" feature from Section IV and selected the threshold with the best sensitivity and specificity (*i.e.*, the one leading to the point on the ROC curve closest to the upper left corner (0,1)).

We used the same procedure described in Section VI-C to train PLR classifiers. Table III shows the resulting AUC values.

VII. Results and Discussion

We found that in each case but one, the non-RBM classifier outperformed its RBM counterpart. Furthermore, when we learned classifiers using the non-RBM and RBM features together, we obtained AUCs that were not substantially higher than those for the non-RBM classifiers. For the remainder of this discussion, then, we focus on the non-RBM classifiers.

A. Predicting Interventions

We found that, given a 60-minute interval, we were unable to accurately predict whether the interval preceded a dextrose administration, blood gas measurement, or ventilator rate increase. To better understand the problems with our models, we ran the classifiers for these three interventions on their respective training sets to compute training AUCs.

For dextrose administrations and blood gas measurements, the training AUCs were low (0.64 and 0.68, respectively), indicating that the classifiers failed to separate even the training examples well. We believe that the most likely explanation for this poor performance is that NICU doctors rely primarily on factors other than the physiological signals in deciding when to order these two interventions. Indeed, one Stanford clinician informed us that he mainly orders ISTAT blood draws after adjusting the ventilator, and thus his choice of whether to order the intervention at a given time does not depend strongly on the infant's physiology. In terms of dextrose administrations, we observed that they generally occurred at regularly spaced intervals that varied in length for different infants, suggesting that doctors set a dextrose administration schedule in advance, rather than based on physiological signals from the past hour. Given that the frequency of dextrose administrations was predictive of BPD, it would be fruitful to investigate how NICU doctors set this administration schedule.

On the other hand, the ventilator rate increase classifier had a training AUC (0.82) much higher than its testing AUC. Thus, it appears that the classifier was overfitting, especially given the relatively small number of examples (146) for this intervention.

We were fairly successful in predicting whether an interval preceded a ventilator setting increase or a ventilator FiO_2 (fraction of inspired oxygen) increase. We note that the two classification tasks were similar, since the majority of setting increases were FiO_2 increases. One of our main goals in creating these classifiers was to identify physiological signatures useful for BPD prediction. To do so, we examined the weights that the two classifiers assigned to the features. Recall that we had normalized feature values so that the weights would be comparable.

We found that all of the highly weighted features for both classifiers were functions of the oxygen saturation (OS) signal. This result was not surprising,

given that NICU clinicians told us that they often adjust the ventilator in response to desaturation events (*i.e.*, periods of low OS). Interestingly, the top features for both classifiers included not only simple functions of the OS signal like mean and variability, but also several features obtained from the signal's discrete Fourier transform (DFT). This observation suggests that the frequency content of the OS signal captures useful information about desaturation events and therefore has potential for BPD prediction.

B. Predicting Measurement Values

The classifier for blood pH performed very well. The other three classifiers were also reasonably successful in differentiating high values from low. As discussed in Section V, these classifiers could be extremely useful in an NICU, giving doctors noninvasive real-time estimates of an infant's blood gas values.

To gain insight into BPD prediction, we examined the feature weights that our classifiers learned. One general observation was that, of our nine total classifiers, eight assigned very high weight to the mean OS feature. This finding raises the question of why the mean OS feature was not among the most predictive of BPD in our initial feature exploration. We hypothesized that the answer was our segmentation of the signal into intervals, and that the distribution of mean OS values over intervals captures more useful information than the signal's overall mean OS. Indeed, we found that the minimum of mean OS values over 60-minute intervals was more predictive of BPD than either the mean or the minimum OS value over the first 5000 minutes. This result demonstrates the benefit of focusing on short intervals of the physiological signals.

Besides mean OS, the measurement classifiers learned high weights for other simple OS features such as variability. Additionally, DFT-based features of the signals appeared frequently among the top features for all four classifiers, again suggesting that the frequency contents of the physiological signals have promise for predicting BPD.

We made two observations that were particularly interesting from a medical perspective. First, we found that the most highly weighted feature for the resistance classifier was a function of the heart rate (HR) signal's DFT. Based on the sign of the weight, periods of high airway resistance are characterized by HR signals with more high-frequency components. This result sheds light on the effect of lung dynamics on heart rate and, more broadly, the interrelation between the respiratory and circulatory systems of premature infants. Our second interesting observation was that both the blood pH and blood oxygen classifiers learned high weight for the correlation between the HR and OS signals. Beyond suggesting a feature for BPD prediction, this link between high HR/OS alignment and low blood pH and blood oxygen levels provides insight into an unhealthy infant's inability to autoregulate body systems.

VIII. Creating an Integrated Model for BPD Prediction

By examining the weights learned by our various classifiers, we identified sixteen features as potentially useful for BPD prediction: four simple OS features, ten DFT features, HR/OS correlation, and mean RR. With the addition of the two physiology-based features found to be predictive of BPD in our initial exploration, we had a set of eighteen features.

Rather than classifying infants as BPD or control, we decided to create a model that would classify 60-minute intervals as BPD or not. We had several reasons for making this choice. First, we saw an example in Section VII-B in which focusing on 60-minute intervals led to a more predictive feature for BPD than working with the entire 5000-minute signal at once. Second, our previous experiments were performed using 60-minute intervals, so some of our features (namely, those based on the DFT) applied specifically to intervals of that length. Finally, we believed that an interval classifier would be more valuable to NICU doctors, as it would let them obtain predictions every hour and thereby gauge changes in an infant's BPD risk over time and with different treatments.

Ideally, we would train and test our BPD interval classifier on data taken from a new set of infants, since we already used data from our current set to create the intervention and measurement classifiers. Unfortunately, as obtaining data for new infants requires significant effort by multiple people to label and pre-process the data into usable form, we were unable to create a new data set within the time frame of the current work.

Instead, we learned a BPD classifier using the same data set from our previous experiments. We started by segmenting each infant's first 5000 minutes of data into 60-minute intervals. We then split the set of infants into a training set (consisting of 10 positive and 10 negative examples) and a testing set. With the eighteen features described above, we trained a PLR classifier on 500 randomly chosen intervals from the infants in the training set, using 10-fold cross validation to select the optimal value of the regularization parameter. We ran the resulting classifier on all of the intervals from the infants in the testing set. To obtain an overall BPD risk score for a given infant in the testing set, we computed the proportion of that infant's intervals that were classified as BPD. These scores achieved an AUC of 0.87. Figure III shows example outputs from the interval classifier.

IX. Conclusions and Future Work

The final product of our project was a physiology-based BPD interval classifier that achieved strong results on our data set. We would like to train and test this classifier on a new and larger set of infants to verify whether accurate BPD prediction is indeed possible with our chosen features.

In addition to developing a BPD classifier, we created nine intervention and measurement classifiers, several of which (most notably the blood pH classifier) performed well and could be very useful in an NICU. We also made a number of interesting discoveries in the course of the project. For example, we found evidence that segmenting a signal into intervals and examining them individually leads to better features for BPD prediction than treating a long signal as a whole. Furthermore, we identified informative features related to signal frequency content and HR/OS correlation, a valuable finding not just for predicting BPD but also for understanding its biological basis.

There are a number of directions in which we would like to extend this work. Given our observation that segmenting a signal into intervals can yield more predictive features, we would like to repeat our experiments using different interval lengths to determine which one is optimal. We are also interested in further exploring the relationship between cross-signal correlation and BPD by developing more sophisticated measures of correlation tailored to our specific application. In terms of learning algorithms, we would like to check whether support vector machines (another widely-used type of classification

algorithm, often referred to as SVMs) can outperform our PLR classifiers.

Overall, this project represents an important step towards developing an accurate predictive model for BPD based on physiological signals alone. If the strong performance of our BPD classifier generalizes to larger data sets, the classifier could be adopted by NICUs to help doctors make more informed treatment decisions. In this way, our work has the potential to substantially improve the care of premature infants.

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References

1. Walsh, M. *et al*. Summary proceedings from the bronchopulmonary dysplasia group. Pediatrics 117(3), S52-56 (2006).
2. Kinsela, J., Greenough, A. & Abman, S. Bronchopulmonary dysplasia. Lancet 367(9520), 1421-31 (2006).
3. Jobe, A. & Ikegami, M. Mechanisms initiating lung injury in the preterm. Early Hum Dev 53(1), 81-94 (1998).
4. Van Marter, L. *et al*. Do clinical markers of barotrauma and oxygen toxicity explain interhospital variation in rates of chronic lung disease? Pediatrics 105(6), 1194-1201 (2000).
5. Garland, J. *et al*. Hypocarbia before surfactant therapy appears to increase bronchopulmonary dysplasia risk in infants with respiratory distress syndrome. Arch Pediatr Adolesc Med 149(6), 617-22 (1995).
6. Yoder, B., Anwar, M. & Clark, R. Early prediction of neonatal chronic lung disease: a comparison of three scoring methods. Pediatr Pulm 27(6), 388-94 (1999).
7. Halliday, H., Ehrenkranz, R. & Doyle, L. Early postnatal (<96 hours) corticosteroids for preventing chronic lung disease in preterm infants. Cochrane Database Syst Rev (1), CD001146 (2003).
8. Khosla, A. *et al*. An integrated machine learning approach to stroke prediction. ACM SIGKDD International Conference on Knowledge Discovery and Data Mining (2010).
9. Saria, S. *et al*. Integration of early physiological responses predicts later illness severity in preterm infants. Sci Transl Med 2(48), 48ra65 (2010).
10. Kaiser, J. The association of high-magnitude cerebral passivity and intraventricular hemorrhage in premature infants. Pediatrics 124(1), 384-86 (2009).
11. Ahmad, S. *et al*. Clinical review: A review and analysis of heart rate variability and the diagnosis and prognosis of infection. Crit Care 13(6), 232 (2009).
12. Saria, S., Koller, D., & Penn, A. Discovering shared and individual latent structure in multiple time series. arXiv:1008.2028v1 [stat.ML] (2010).
13. Lee, H., Ekanadham, C. & Ng, A. Sparse deep belief net model for visual area V2. NIPS (2007).
14. Zhu, J. & Hastie, J. Classification of gene microarrays by penalized logistic regression. Biostatistics 5(3), 427-43 (2004).

Laney Kuenzel is a junior from Cleveland Heights, Ohio. She is double majoring in computer science and math. Besides doing research, she enjoys tutoring, running, and working for the Stanford Flipside.

The perfect storm: The politics, policies, and people of the USA Patriot Act

Siddharth Damania

This paper explores how the convergence of three streams – the problem, the politics, and the policy – helped create the 2001 Patriot Act. Using political methodology outlined by John Kingdon, the legislative success of the Patriot Act seems to be substantiated by the confluence of the three streams: security holes (the problem), American outcry against the 9/11 attacks (the politics), and the bullish measures encompassed in the Patriot Act (the policy). The research in this paper expounds upon the role of these streams in the formation of the Patriot Act and how they were framed in specific ways by political personalities. The conclusion suggests that the ultimate passage of the Patriot Act can be explained by both the manipulation of public opinion and the use of a range of unorthodox tools for lawmaking.

Merely a month and a half after the terrorist attacks of 9/11, Congress and President George W. Bush enacted one of the most important laws concerning government intrusion into private lives, the USA Patriot Act (officially, Uniting and Strengthening America by Providing Appropriate Tools Required to Intercept and Obstruct Terrorism Act). "This was one of the most fundamental pieces of legislation relating to the Bill of Rights in the history of our country," Senator Russ Feingold claimed shortly after the passage of the Patriot Act. The 2001 bill had the goal of deterring and punishing terrorist activity in the U.S. and around the world with the aid of enhanced "law enforcement investigatory rules," a subtle euphemism for unprecedented permission for the federal government to wiretap and search telephone, email, and financial records. "It was a low point for me in terms of…somebody who believes in civil liberties," Feingold remarked (qtd in Foerstel 36). Ninety eight Senators voted Yea; Feingold was the sole dissenter. How was it possible, in the context of a liberal yet unobtrusive and small-state political culture, that a law affording government access to almost every important aspect of private life could pass with such swiftness and accordance?

The much-discussed unity and outrage following 9/11 certainly presented Congress and President Bushwith a political opening, but the attacks themselves cannot fully explain how policymakers could pass a bill of such size and significance with minimal debate (Foerstel XVII). Instead, 9/11 opened what political scientist John Kingdon would call a policy window. By looking at Kingdon's analysis of agenda-setting and policy formation, we see a clearer, formula-driven process by which the Patriot Act came to fruition. Kingdon explains that policy finds high standing on an agenda when the three "streams" of problem, politics, and policy converge and help open the policy window, a period of time when movement on an issue is much more possible. Although Kingdon lays out a framework for interpreting and comprehending public policy, his analysis is confined to merely that: a framework. Actual public policy has many more intricacies that convolute the entire process. Regardless, Kingdon's theoretical structure provides a useful starting point to explore policy formulation, and the Patriot Act is a prime example of this political process. The legislative success of the Patriot Act seems to be substantiated by the confluence of the three streams: legitimate security holes (the problem), American outcry against the attacks (the politics), and the bullish measures encompassed in the Patriot Act (the policy).

This paper first seeks to understand how these streams converged to produce, in retrospect, one of America's most controversial laws. We will then take a closer examination at the complexities of two of the streams, those of the politics and the policy, to see how each was subject to significant political engineering. In particular, both politics and policy were manipulated by the Bush administration and shaped to procure legislative success. Ultimately, we find that the Patriot Act is an exemplar of Kingdon's agenda-setting theory, but also a case in point of the intricacies that muddle any simplification of public policymaking.

I. The Three Streams' Convergence in the Patriot Act

The Patriot Act is unique among other landmark legislative feats because it was passed so quickly, a fact which becomes unsurprising when put into context. The U.S. had just experienced the worst terrorist attacks in its history, and the astonishing networks and organizational abilities of the terrorist groups revealed that America was not immune from future attacks. Though it would not be released until nearly three years later, the 9/11 Commission reported what was blatantly obvious in the direct aftermath of the attacks: U.S. intelligence gathering was fragmented and poorly coordinated ("9/11 Commission"). Kingdon suggests that, though the definition of the problem is expansive, it is best regarded as a change in the state of a system. He further argues that, while some problems capture the attention of people by systematic indicators of the issue at hand, some problems arise from a dramatic event (Kingdon 90). Intelligence and security failures preceding the Patriot Act certainly represented the latter. Kingdon notes that the problem is not always self-evident from the indicators themselves, but can be prodded by a focusing event, like a crisis or disaster. National security is a perennial concern, and it had actually been elevated in Congressional discussion in 2001 with the election of George Bush. However it was only through 9/11, "the sort of thing government decision makers cannot ignore," that intelligence and security could "[move up] from a less visible arena on [the] governmental agenda" (Kingdon 95). The scope of the day's tragedy highlighted the problem of lackluster knowledge about these terrorists' operations. The terrorist attacks were a vehicle to demonstrate that there was a clear problem with U.S. intelligence and security, and that major legislation was necessary.

The politics stream was a crucial element in making the Patriot Act an active agenda item. Americans' outpour of patriotism and zeal for avenging 9/11 was well-documented, ex post, and had a significant impact on the political climate. Bush's approval rating stood at an astronomical

90% less than a month after 9/11. Studies of the American public by Andre Kohut of the Pew Center demonstrated that the country's burst of unity and patriotism was coupled with a strong desire for security and activism in the face of attacks on the American homeland:

> I think the public's need for protection is apparent in big bold letters in every poll I've seen. Support for increased defense spending stands at 60 percent—triple what it was four years ago, and funding for homeland defense is just as high if not higher… I should add that the public continues to strongly support the use of force to combat terrorism. (Kohut)

Clearly, the political environment of the aggregate American population fostered an atmosphere that was more amenable than ever to the measures outlined in the Patriot Act. As we see later, though much of these huge upswings were a function of Bush administration manipulation, they had a profound impact on policymaking. But while public sentiment was vital to the passage of the Patriot Act, the political climate among policymakers was also important in boosting the issues to a decision agenda and helping to open a policy window. Bush's declaration of a War on Terror on the night of September 11th, coupled with immediate backing from most of Congress created a perceivably united front that seemed to embrace the measures necessary to quell any possibility of future attacks. Senate Majority Leader Tom Daschle assured Americans that Republicans and Democrats, the House and Senate stood "strongly united behind the president". As we discuss later, however, there was much internal discord in Congress over the Patriot Act, even as the visible politics proffered unanimity.

A closer look at the timeline of the Patriot Act's Congressional proceedings suggests a distinct policy stream that converged with the problem and politics to produce the final legislation. Deliberation on the Patriot Act was defined by haste, and "the pressure on Congress to do something dramatic to protect the country from terrorist attacks was overpowering" (Foerstel 30). The Bush administration was keen on near unanimity, as it believed that any modicum of opposition could portray weakness. Limited debate and temporal proximity to 9/11 would ensure speedy passage and minimal resistance. This strategy worked, as even Tom Daschle came out to strike down any opposition or amendments to the bill. Later we show how a sense of contrived urgency helped proponents enact the toughest policy measures possible while entertaining little debate. Moreover, we see that this urgent lawmaking process induced unconventional lawmaking, a strategy that both helped the bill pass and portray bipartisanship. Kingdon's definition of the policy community of specialists was never restricted to merely legislators; instead, it included "bureaucrats, people in the planning and evaluation and in the budget offices, Hill staffers, academics, interest groups, [and] researchers" (Kingdon 87). With this broader umbrella classification, we find the heart of the policy movers in the case of the Patriot Act. The Department of Justice, led by Attorney General John Ashcroft, drove the process, making their own versions of the policy the one to be voted upon. Representative John Conyers (D-MI) lambasted the process: "How, in a time of urgency and crisis, could the Attorney General decide to become a legislative member and replace all 43 members of the House Judiciary Committee?" (qtd in Foerstel 32). The bill which the Department of Justice produced was much stronger than congressional drafts of the bill, as it called for indefinite detention of any noncitizen suspected of facilitating terrorism, unchecked sharing of eavesdropping data throughout the government, and weaker FISA standards for surveillance authority (Foerstel 33). Ultimately, the policy stream played a significant role in the Patriot Act's legislative triumph. Due to strategic proximity to 9/11, the Act was able to pass with harsh measures otherwise unlikely to be ratified. Moreover, the bill came out of Congress as a virtually unanimous, bipartisan success because of the hurriedness forced on the legislators, who had little choice but to approve the Bush administration's legislative demands.

The terrorist attacks of 9/11 opened a wide policy window for action on U.S. security and intelligence. The problem, politics, and policy, then, each played a crucial role in moving the issues raised by 9/11 onto a different agenda sphere, making it a top decision priority for the federal government. The rushed enactment of the bill represents a perfect storm of these three aspects and the basis upon which some of America's most controversial legislation was passed.

II. The Manipulation of Public Opinion

Following 9/11, there was a well-documented sense of unity that pervaded the country: Bush's approval ratings soared to 90%, Congress was willing to act in a bipartisan manner, and the American public constructed a steely wall of unity to both prevent further acts of terror and to "bring to justice" the terrorists who committed the acts (Foerstel 30).

Many key actors played crucial roles in the legislative effort to equip the federal government with the tools to protect the American homeland, but none held as significant a function as the American public itself. Without overwhelming public support, Congress and the President could scarcely have passed an act that would "temporarily abridge individual liberties in ways that would never be considered in more halcyon times" (Abdolian, 1446). According to Kingdon's framework, the American public's receptiveness to the Bush administration's requests for policy action was a key component in bringing the political stream in line with the other streams. But central to an analysis of the politics of the Patriot Act is an understanding of the non-linear relationship between initial public response to 9/11 and the eventual passage of the Patriot Act. Though a surface-level examination might suggest that public outcry after the attacks directly led to the landslide legislative success of the Patriot Act, this inquiry fails to note the importance of how, precisely, public opinion came to have such forceful bearing on Congress. Instead, public opinion in the case of post-9/11 politics is best understood by how it was framed and manipulated for a specific purpose by the Bush administration. Stanford Political scientist David Brady suggests that there is a general correlation between mass opinion and policy. We can extrapolate from his work that the role of the President and the Department of Justice in molding public sentiment towards anti-terrorism legislation was one of the "intervening variables between public opinion and policy results" (Brady 1). Specifically, Brady cites the widely-held view that presidents have a powerful ability to organize and persuade in an effort to both shape and shift public opinion. Congress, then, "is most often viewed as a responder to opinion" (Brady 3). This seems to be precisely the case in the lead up to the final voting on the Patriot Act. Public opinion was formed by the tragic events of 9/11, but also, in part, by the political engineering of

the Bush administration – specifically to gain support for the sweeping Patriot Act. Though there are certainly instances in history where the cornerstone of American policy has been the public's pressure on the federal government and, in particular, the President, this reverse link is much weaker in the case of the Patriot Act. This is due, in large part, to the nature of the political climate following 9/11, when the public felt outrage and desired decisive action, but was largely vague about the precise steps that should be taken. Public opinion, instead, was malleable and open to persuasion by the President. Perhaps, the public also had some effect on the President and his administration. However there has been much documented literature on the Bush administration's obstinacy on this matter, so this theory is weak. Herbert Foerstel in *Patriot Act* implies that the administration had a clear agenda and was not willing to be driven away from its aims by arguments on policy merits and civil liberties concerns:

> The Bush Administration wanted to rewrite the entire body of law defining and limiting government surveillance…In reality, the Patriot Act was not a bold new anti-terrorism bill. It was a resurrected wishlist of executive powers that had accumulated in the Justice Department over many years, powers that when conceived, had little or no relevance to terrorism and which Congress rejected as unnecessary infringements on civil liberties. (Foerstel 30)

In the case of the Patriot Act, then, it more telling to examine the effect of the President on the public, and not vice versa. Precisely, we seek to understand the means through which public opinion was shaped after 9/11 and how it was used to influence such controversial anti-terrorism policy.

Before embarking on an examination of the most influential actors involved in construction and channeling of the Patriot Act, it is helpful to compare it with its predecessor of sorts: the Anti-Terrorism and Effective Death Penalty Act of 1996 (AEDPA), a bill President Bill Clinton signed into law after the Oklahoma City bombing in 1995. Provisions of the AEDPA largely limited federal courts' powers to grant relief on death penalty rulings. Like the events of 9/11, the attack on Oklahoma City's Murrah Federal Building had a profound impact on the public's opinion regarding the death penalty, but President Clinton's role in crafting that opinion is also of great significance. The AEDPA was one of Clinton's more controversial measures, but one in which he experienced "success in reframing the crime debate" for his party and one that, ultimately, was "directed more toward voters' perceptions of the weaknesses of the criminal justice system than a reasoned response to an actual terrorist threat on American soil" (qtd in Federman 163). In this case, we see the fruition of Brady's linkage from Presidential persuasion to public softening, which ultimately led to Congressional action (in the case of the AEDPA, the law passed 91 to 8 in the United States Senate, and 293 to 133 in the House). The key node in this relationship is the tying of two branches by the powerful role of public opinion.

In many ways, the political conditions under which AEDPA was passed laid both the framework and the mechanism for the passage of the Patriot Act in 2001. As noted earlier, a general call to action was issued by Americans following 9/11, but Bush and the Department of Justice capitalized on this public vulnerability. Scholars suggest that the administration focused on "strategic political communication" and aimed to gain monopoly-like control over information and outlets that might influence public opinion (Domke 292). An estimated 82 million Americans watched the President's address to Congress nine days after the attacks, an event that offered an immense stage for the President to leverage American support in pressuring Congress to pass the most stringent anti-terrorism measures.

A consistent perspective was a crucial element to the administration's successful dissemination of its agenda. Instead of being plagued by the familiar problem of political infighting and off-script communication that weakens the message and undermines its importance, the Bush administration presented its case with one voice. Domke *et al*. predict that this had a significant effect on promoting public approval and subsequent congressional success: "President Bush [and the administration] presented a unified message about the anti-terrorism legislation and the perceived need for its congressional passage" (Domke 293). Coupled with the strategy of offering a consistent perspective, the administration sought to shape public discourse by echoing news coverage. Government officials made a concerted effort to ensure that the administration's communications about the proposed Patriot Act would be in unison with news content about the act. And while the media is often credited with being a stalwart critic of the government's ideas and conceptions, 9/11 provided a unique instance wherein dissent in the news coverage of the Bush administration's work was rare (Domke 295).

So what were the results of these efforts to influence public responsiveness towards civil liberties restrictions? Just days after the attacks, 55% of U.S. adults claimed it would be "necessary for the average person to give up some civil liberties in order to curb terrorism in this country." A week later, that number had risen to 63%. Two weeks later, 72% said the administration's proposed degree of restrictions on civil liberties were "about right," with an additional 17% saying the administration was not going far enough (Domke 306). Nearly 90% of the public, therefore, were unfazed by the proposed quelling of civil liberties.

The Bush administration's cumulative efforts to sway public sentiment towards the Patriot Act had certainly materialized in the polls, but that opinion's weight on legislative action was of equal, if not more, importance. The claim that "national unity is good politics" during crises seems to have rung true. The newly framed public opinion on anti-terrorism law had significant bearing on legislators and was likely the reason why 98 senators voted in favor of the otherwise unfathomable bill. Domke explains:

> Publicly stated rationale among senators for their voting decisions and occasional congressional comments about the press are suggestive that the themes and perspectives emphasized by the administration, and echoed substantially in news content, contributed to congressional decision making and debate. (Domke 308)

Though it is difficult to precisely measure the role public opinion alone plays in lawmaking, as David Brady notes, it can be inferred from public opinion pressure on politicians and their specific agendas. We must also note another factor at play in the politics of the Patriot Act. Unlike other landmark legislative acts – especially those that are contentious in nature – the process of debate can be protracted, which can invite further evidence and discussion

against the proposed reform. Because the Bush strategy was so successful in creating such an end-of-spectrum and overpowering public view on anti-terrorism, it was much easier for the Bush administration to ensure swift congressional approval.

The attacks of 9/11 certainly created a general sense of both public unity and a call for action. But behind these events was a very specific chain of politics that resulted in passage of the highly controversial Patriot Act. Like in the case of the AEDPA just five years earlier, the President used many techniques of strategic political communication to fundamentally formulate opinion on the piece of anti-terrorism legislation. This crushing force of public opinion, then, was the necessary link to attain congressional backing of the bill.

III. Urgent Lawmaking and its Role in Policy Formation

While the overpowering public pressure placed on Congress to pass the Patriot Act played a foremost role in its legislative success, it is also important to understand the precise policy formulation steps that took place behind the chamber doors. Though bipartisanship was the public hallmark of post-9/11 anti-terrorism legislation, the lead-up to the bill's ultimate passage was a process of intense disagreement, controversy, and eventual compromise. The natural questions are why and, more specifically, how did the Patriot Act pass in both chambers within seven weeks of 9/11? We have already seen how hawkish public sentiment – in large part carved by the Bush administration – focused Congressional attention on bringing to the floor and passing strong antiterrorism legislation. But behind this story were strategic legislative tactics that helped in getting the Patriot Act passed. Specifically, an inflated sense of urgency comprised the framework of proponents' approach to legislative success. This exigent lawmaking made for an unorthodox political process, resulting in a rushed bill falsely trumpeted for its bipartisanship. Barbara Sinclair, author of *Unorthodox Lawmaking*, would argue that the making of the Patriot Act was characterized by a "series of decision points where more complex choices are at issue" (Sinclair 218). Here, we seek to recount the urgent Patriot Act lawmaking process that induced unconventional lawmaking and demonstrate how this strategy both helped the bill pass and assisted in portraying bipartisanship.

Before looking at how the Patriot Act was created and examining the process through which an overwhelming majority of Congress approved it, it is necessary to reexamine the context in which it was brought to the political forefront. The attacks of 9/11, the worst attack on the American homeland, had elicited a strong response in the federal government, and while the merits of the Patriot Act might have been hotly contested, there was a clear unity among American leaders that something needed to be done (Domke 306). In step, many Democrats were fully in favor of the proposed antiterrorism legislation from the beginning. Prior to 9/11, both chambers had been debating the "Departments of Commerce, Justice, and State, the Judiciary, and Related Agencies Appropriations Act" (H.R. 2500), but had been largely stagnated. The two days following the attacks brought a slew of harsh and hastily considered antiterrorism measures that broadened the grounds for emergency surveillance by the Department of Justice. The Senate's adoption of these measures and swift passage of the bill on September 13th, 2001 were early signs that Congress, more than before, was acting as one and doing so in a very hurried manner, symptomatic of what was still to come (Howell 1151).

Urgency and special procedural processes are key concepts that defined Patriot Act legislating. Though bills traditionally originate in one of the chambers, the legislation that would become the Patriot Act took a different course. Six days after the attacks, Attorney General John Ashcroft called on Congress to quickly pass the administration's yet-to-be-drafted antiterrorism proposal, skimping on details but forceful on the need for haste. The chief alternative to the Justice Department's measures was Senate Judiciary Committee Chair Patrick Leahy's "USA Act," which enumerated many national security enhancements but placed more checks on the federal government's surveillance abilities (Howell 1152). With the administration and Leahy's proposals unveiled, the strategic rhetoric of urgency by Patriot Act proponents, headed by the Bush administration and Republican lawmakers, began to take life.

On September 24th and 25th, the Attorney General testified before the House and Senate Judiciary Committees, but curiously spent little time on the specifics of the administration's proposal, instead harping on the present terrorist threat and the urgency with which Congress must approve the antiterrorism legislation:

> [T]he American people do not have the luxury of unlimited time in erecting the necessary defenses to future terrorist acts… Every day that passes with outdated statutes and the old rules of engagement -- each day that so passes is a day that terrorists have a competitive advantage. Until Congress makes these changes, we are fighting an unnecessarily uphill battle. (Ashcroft)

Deviating from standard procedure, Ashcroft spent minimal time and limited scope answering questions following his ambiguous presentations, taking few questions and avoiding civil liberties concerns. On a talk show the following weekend, Ashcroft stated: "Talk will not prevent terrorism. We need to have action by the Congress" (Howell, 1161). Republican Senator Orinn Hatch agreed, saying, "I don't think we can delay it any longer" (Mitchell and Purdum). The approach of bypassing operating frameworks to quickly pass the bill was quite evident to outside commentators. One editorial feared the process that was taking place: "While we have serious concerns about some provisions in this legislation, we have even greater concerns about how the administration and congressional Republicans are trying to rush this package of antiterrorism laws through Congress with little debate or analysis" (St. Petersburg Times).

But even while the administration's insistence on urgency was not swaying some lawmakers, it was certainly having an effect on the procedures by which the law was being considered in Congress. Aimed at "expediting the bill's passage in deference to the administration," Senator Harry Reid announced on October 9th, 2001 that the USA Act– which would later be incorporated as part of the Patriot Act – would be held at desk, bypassing normal procedures by skipping committee referral (Howell 1167). According to Sinclair, the bill sponsor and committee usually play the most important role in floor debate, but bypassing the committee stage "speed[s] up the process significantly" (Sinclair 219). Majority Leader Daschle, moreover, requested unanimous consent to take up the bill with limited amendments, a move that also expedites legislation (Sinclair 220). And though there were complaints from both sides of the aisle about these proce-

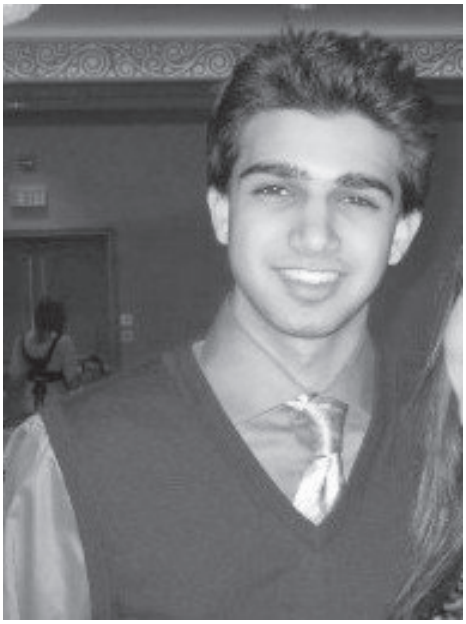
dural shortchanges, the mantra of urgency proved undefeatable. Senator Feingold, the lone dissenter in the final vote for the Patriot Act, was disappointed in the nature by which the bill had moved through Congress. "There has not been an open process in the Judiciary Committee, much less the full Senate, for Senators to have the opportunity to raise concerns about the how far this bill goes in giving powers to law enforcement" (qtd. in Weiner).

Eventually majorities in both the Senate and House passed the USA Act, just one month after 9/11. Further evidence of unorthodox lawmaking, Republican House leaders chose not to request a conference to reconcile the difference bills from each chamber, catching many Democrat opponents off guard (Howell 1174). Leahy admitted that he had "acquiesced in some of the administration's proposals…to preserve national unity in this time of crisis and to move the legislative process forward," in the hopes that some of his misgivings would be resolved in the conference stages *(Bash)*. Republicans urged that a conference would merely delay granting the powers vitally needed by law enforcement. Without conference, there was little structure to discussion on the two bills. Ultimately, the House introduced a version of the bill, called the Patriot Act, which compromised the two bills. The House quickly passed the bill, and the Senate followed suit the next day, October 25th. The President's signature the following day made the Patriot Act into law (Howell 1178).

Clearly, the creation of the Patriot Act was a product of quick lawmaking, being passed merely seven weeks after 9/11. The evidence suggests that the federal government injected a sense of urgency into the political process, a strategy that helped place immense pressure on elected officials to bypass traditional procedures in favor of a more rushed process. This speed materialized in untraditional policy formulation, including deviations on the origination of the bill, the scope and time of debate, voting procedures, and legislative processes (conferencing, amendments, etc). The claim here is that the urgent, and, in turn, unorthodox lawmaking processes helped pass the bill and did so in a perceivably bipartisan way. Under this strategy, proponents of the legislation were able to successfully quell most of the debate brought on by the opposition. By offering few specific answers to the many questions raised by the bill and cutting many of the checks and balances, like committee referral and the ability to add amendments, proponents took away vocal and legislative power from those most vested in the bill's intricacies. Circumventing established processes like conferencing and filibustering, moreover, deprived the minority of even the most modest legislative power they could wield. In a self-serving and propagating fashion, the more questions the opposition asked, the more pressure Republicans were able to place on Congressional Democrats, under the guise that the opposition was not protecting Americans against future attacks. These tactics generated another important benefit for the administration. The short seven-week process and dearth of visible debate in Congress, engendered the appearance of bipartisanship. By churning out such an enormous bill in such little time, it seemed unlikely to the public that the bill could have been hotly contested. The rushed process behind chamber doors, therefore, gave the public an illusion of near-absolute unity among Congressmen. In a bill of such significant consequence and presumable controversy, it was important for the Bush administration to achieve bipartisanship, giving the President a mandate for the government's future policy proposals.

The chief objection to this outlined story is that, regardless of any legislative manipulation that took place in Congress, the passage of the Patriot Act was inevitable. Given the political atmosphere following 9/11 and the public pressure placed on Congress to act, this is not an unlikely assumption. But to be certain, the special procedures likely did help the Patriot Act, as Sinclair's research suggests that the likelihood of legislative success has a direct relationship with the number of special procedures and practices employed (Sinclair 223). Sinclair's theories do not seem to hold in the context of amending. Though Sinclair's work suggests that "the adoption of floor amendments may enhance a bill's chance of ultimate legislative success," the Senate's refusal to participate in amending activity does not seem to have hurt its political prospects. The explanation for this special case seems to be the context. Unlike other bills, post-9/11 legislation had two important characteristics: public unanimity and an outcry for speed. Amending would not have influenced the outcome of the Patriot Act greatly because there was knowledge, from the beginning, that amendments would not be welcome. The political wrangling had to be done in the early stages. More interestingly, it is important to note the effects of unorthodox lawmaking in this context. Not only did they provide the administration with this legislative victory faster than otherwise, these procedures also provided a bipartisan mandate that would later prove to be invaluable to the Bush administration.

References
1."9/11 Commission Faults U.S. Intelligence." CNN.com. Cable News Network, 14 May 2004. Web. 9 Apr. 2010.
2. Abdolian, Lisa, and Harold Takooshian. "The USA Patriot Act: Civil Liberties, the Media, and Public Opinion." Fordham Urban Law Journal 1453rd ser. 30.1429 (2003). Web. 28 Apr. 2010.
3. Bash, Dana. "Senate Passes Anti-terrorism Legislation." CNN.com. Cable News Network, 12 Oct. 2001. Web. 15 May 2010.
4. Brady, David. Public Opinion and Congressional Policy. Schickler. Web. 27 Apr. 2010.
5. Domke, David, Erica Graham, Kevin Coe, Sue John, and Ted Coopman. "Going Public as Political Strategy: The Bush Administration, and Echoing Press, and Passage of the Patriot Act." Political Communication 23 (2006): 291-312. Web. 26 Apr. 2010.
6. Federman, Cary. The Body and the State: Habeas Corpus and American Jurisprudence. Albany: State University of New York, 2006. Print.
7. Foerstel, Herbert N. The Patriot Act: A Documentary and Reference Guide. Westport, CT: Greenwood, 2008. Print.
8. Howell, Beryl A. "Seven Weeks: The Making of the USA Patriot Act." The George Washington Law Review 72 (2003-2004): 1145-207. HeinOnline. Web. 14 May 2010.
9. Kingdon, John W. Agendas, Alternatives, and Public Policies. New York: Longman, 2003. Print.
10. Kohut, Andrew. "The Impact of September 11 on Public Opinion: Increased Patriotism, Unity, Support for Bush; More Interest in News." Proc. of A Brookings/ Harvard Forum: Press Coverage and the War on Terrorism, The Brookings Institution, Washington, D.C. 27 Mar. 2002. Web. 9 Apr. 2010.
11. Mitchell, Alison, and Todd Purdum. "A Nation Challenged: The Lawmakers; Ashcroft, Seeking Broad Powers, Says Congress Must Act Quickly." New York Times. 1 Oct. 2001. Web. 16 May 2010.
12. Sinclair, Barbara. Unorthodox Lawmaking: New Legislative Processes in the U.S. Congress. Washington, D.C.: CQ, 2005. Print.
13. Testimony Before the House Committee on the Judiciary September 24, 2001, 107th Congress Cong. (2001) (testimony of Attorney General John Ashcroft). Print.
14. Weiner, Lauren M. ""Special" Delivery: Where Do National Security Letters Fit into the Fourth Amendment?" Fordham Urban Law Journal 33 (2006). Goliath. Web. 16 May 2010.
15. "Why the Rush?" Editorial. St. Petersburg Times 25 Sept. 2001: 10A. Tampabay.com. Web. 15 May 2010.



Siddharth Damania is a junior majoring in Economics and Public Policy. His professional aspirations include management consulting and financial services. Siddharth has worked with PEER Venture Partners in the Silicon Valley and has been a strategic intern for Pearson Education and State Farm. On campus, Siddharth has been involved with the Stanford Economics Association, the Stanford Pre-Business Association and research at SIEPR. He is also a member of Basmati Raas, a nationally award-winning Indian dance team that competes across the country during the school year.

The Voting Rights Act in the 21st century: Reducing litigation and shaping a country of tolerance

Adam Adler, M. Kousser

For 45 years, the Voting Rights Act (VRA) has protected the rights of millions of citizens across the country. Though the act is significant in its entirety, two sections stand out—Section 2 and Section 5. Section 2 of the act allows individuals and organizations across the country to challenge discriminatory or unjust election policies. Section 5 requires that specifically identified jurisdictions gain the approval of the U.S. Department of Justice or the District Court of the District of Columbia before implementing any changes to election laws or practices. Though Sections 2 and 5 have each worked to stop or prevent racially discriminatory policies, they do not share a uniform history. Legal challenges and congressional amendments have often affected one of the sections, while not directly changing the other. In this paper, I seek to determine the impact of federal and Supreme Court cases on the effectiveness of the Voting Rights Act as well as the extent to which the act enabled minorities and civil rights advocates to eliminate discriminatory policies without litigation. First, I used court documents, files from the Department of Justice, and a variety of other sources to build upon an extensive database of voting rights related legal incidents. Next, using this database along with a record of important federal voting rights cases, I compared the number of voting rights events before critical cases with the number of events after critical cases. I found that significant federal cases, as identified by political scientists and historians, had a large impact on the number and type of discriminatory policies employed by local jurisdictions. Finally, I used the database to analyze the distribution (by time and location) of "non-litigated successes" (NLSs) and found that the presence of successful voting rights act events in a given area, on average, led to a significantly larger number of NLSs in that area.

In 1870, in the midst of the Reconstruction Era, the Fifteenth Amendment to the Constitution was ratified, stating that "The right of citizens of the United States to vote shall not be denied or abridged by the United States or by any State on account of race, color, or previous condition of servitude." While the Reconstruction Congress attempted to quell violence, corruption, and other barriers to black enfranchisement, their efforts were largely ineffective. Opponents of black and minority enfranchisement circumvented the amendment through poll taxes, literacy tests, racial gerrymandering, and a variety of other Jim Crow tactics (Kousser 53).

These attempts to undermine the Fifteenth Amendment and to disenfranchise minority voters continued well into the 20th century. As the Second Reconstruction began, Congress passed the Civil Rights Acts of 1957 and 1960, however these acts also did very little to end voter disfranchisement.

It was not until 1965 that Congress passed the Voting Rights Act (VRA), the first piece of legislation powerful enough to enforce the Fifteenth Amendment. The VRA explicitly outlawed literacy tests and increased the tools available to both the government and to minority groups so that they could mount an effective legal strategy against discriminatory policies. Since its passage, the VRA has been renewed and modified four times to continue to protect the voting rights of minority groups.

Between each of these renewals and modifications, the VRA was the subject of several constitutional challenges and federal lawsuits. In this paper, I use an expansive database of voting rights litigation to determine, first, that the constitutional challenges to the VRA had a significant effect on the number and types of cases brought under the VRA, and second, that the presence of successful voting rights cases in a given area has led, on average, to a significantly larger number of settlements and non-litigated successes in that area.

Section 2 & Section 5

The database I used to reach my conclusions consisted of cases arising under two parts of the VRA—Section 2 and Section 5. Section 2 grants standing to minority groups and individuals across the country, as well as to the U.S. Department of Justice (DOJ), to challenge discriminatory voting laws and policies under more favorable procedures and standards than the Fourteenth and Fifteenth Amendments offer. Section 5 requires certain jurisdictions, principally in the Deep South, to file for preclearance with the DOJ or the U.S. District Court of the District of Columbia before they put changes in their election procedures into effect. This preclearance is designed to stop discriminatory policies before they can be implemented. If a districting plan, election policy or voting method is rejected by the Justice Department after it is submitted for preclearance, the covered jurisdiction must either modify its election policies or prove to a federal court that its policy is not discriminatory (both in its intent and its effect). In automatically scrutinizing every modification in election policy and in shifting the burden of proof to local jurisdictions, Congress' policy, when enforced[1], functioned as an effective road block to discriminatory policies (Kousser 680).

More Information Requests

Though Section 5 objections issued by the DOJ have prevented many discriminatory policies, the objections themselves are not the only way in which Section 5 has influenced election policy. Changes are also caused by More Information Requests (MIRs) (Fraga). As part of the Section 5 objection process, the DOJ regularly issues MIRs when it does not have enough information to decide whether or not it should issue an objection. Often, MIRs telegraph the DOJ's intention to issue an objection. Accordingly, many jurisdictions change their proposed policies to avoid an objection. These MIR-induced changes can take one of three forms: a jurisdiction could withdraw its proposed change, modify the change, or supersede the change by sub-

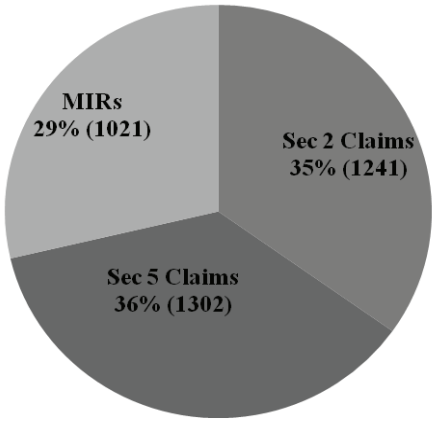


Fig. 1 Claims for the Voting Rights Act, by type

mitting a completely new proposal. Since 1980, the DOJ has issued thousands of MIRs, which has led to over one thousand MIR-induced changes.

Previous Work

Despite its success, Section 5 has been the subject of criticism and constitutional challenges since its inception. Some have argued that the Section violates the Fourteenth and Fifteenth Amendments, while others suggest that it violates states' rights by allowing federal micromanagement of state policies. One of the more recent criticisms of Section 5 is leveled against its coverage scheme (Petitioner's Brief in *NAMUDNO* 27). The current coverage scheme was constructed in 1965 and modified in 1970 and 1975. It covers any jurisdiction which used a literacy test and which had low voter turnout among minorities in the 1964 presidential election (Department of Justice). The coverage scheme was slightly modified in 1970 and 1975 when the act was renewed, but the basic formula has not changed in over 30 years (See Appendix C). Today, over 40 years later, some claim the coverage scheme is unfair because it does not take into account changes in the attitude or demographics of the county.

To that effect, one of the covered jurisdictions in Texas filed a lawsuit contesting the validity of the coverage scheme. In *North Austin Municipal District No. 1 v. Holder,* the Supreme Court unanimously decided to allow the district to opt out of the Section 5 requirement. At the same time, the opinion of the court questioned the validity of the coverage scheme, stating that "The evil that §5 is meant to address may no longer be concentrated in the jurisdictions singled out for preclearance. The statute's coverage formula is based on data that is now more than 35 years old, and there is considerable evidence that it fails to account for current political conditions" (2009). In questioning Section 5, the Supreme Court was, in essence, suggesting that it might rule the coverage scheme unconstitutional in a future case if Congress does not modify it in the near future (Pildes).

Last year, as part of a previous study, I used files from the DOJ, the American Civil Liberties Union, the National Association for the Advancement of Colored People, and a variety of other sources to compile a comprehensive database of discriminatory incidents and policies in the field of voting rights. I used this database, along with census information from the past several decades, to create several alternate coverage schemes for Section 5 of the VRA.

Purpose and Methodology

Though *NAMUDNO* is the most recent challenge to the VRA and to Section 5, there have been many cases leveled against both Section 2 and Section 5 of the act. Although these cases have changed the effectiveness of the VRA over the years, no one has ever analyzed, quantitatively, the impact these cases have had on voting rights litigation or on the necessity of voting rights litigation. Using an expanded version of the database I built last summer, I wanted to determine the extent to which important voting rights cases influence litigation under the VRA. Additionally, I hoped to determine the extent to which the VRA enables civil rights activists to end or prevent voting discrimination without resorting to litigation. My hypotheses were first, that major voting rights cases, as identified by most political scientists and historians, would be associated with large changes in the number of litigated voting rights events, and second, that a large number of voting rights events under Section 2 and Section 5 of the VRA were non-litigated successes (NLSs).[2]

I tested these hypotheses in two steps. First, I used a variety of sources including a database of MIRs, private litigation and settlement records, and numerous academic texts on voting rights to add thousands of additional entries to the voting rights database. Next, using the extended database, as well as a statistical software package and mapping software, I analyzed the number and distribution of events, both litigated and non-litigated, under the VRA both before and after influential Supreme Court cases involving the VRA.

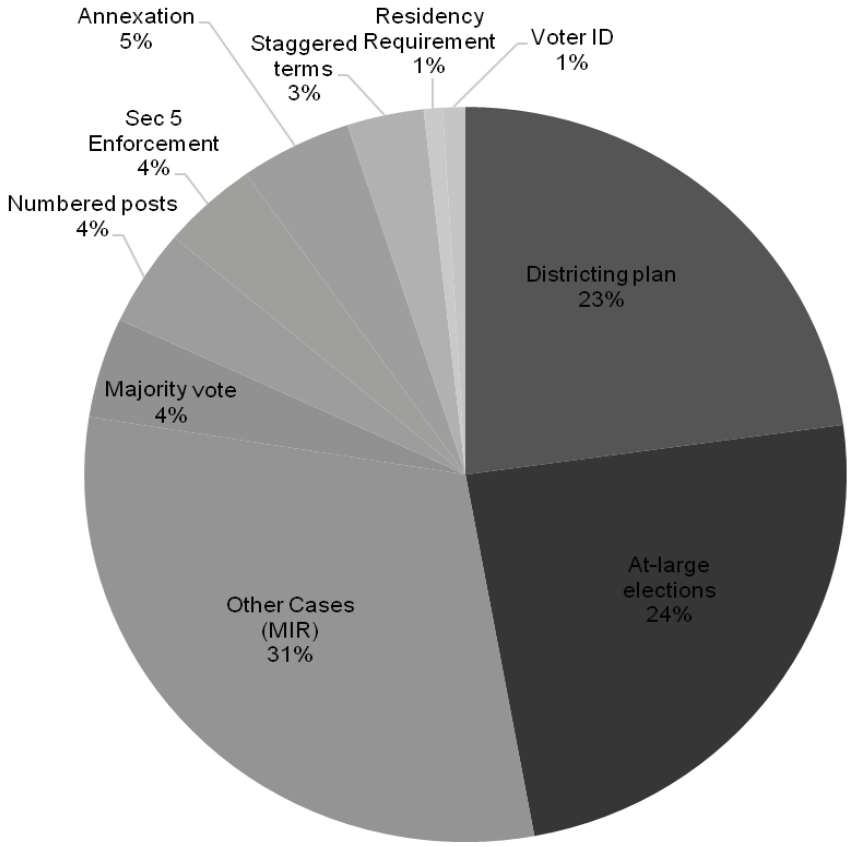


Fig. 2 Claims for the Voting Rights Act, by content

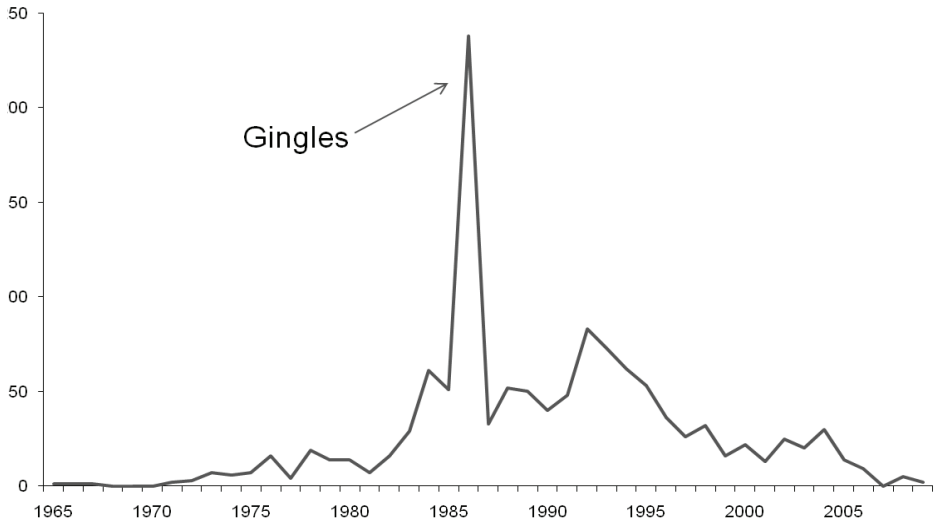


Fig. 3 Section 2 claims increased following a 1982 amendment that made it easier for plaintiffs to win cases by lowering the standard to prove the policy was discriminatory. Two years later, during the next major election year, there was an even larger increase. In 1986, the Supreme Court affirmed the constitutionality of Section 2 in *Thornburg v. Gingles*, leading to a record number of cases filed.

The Impact of Amendments to the VRA and Supreme Court Decisions

After cataloguing and assembling the extended database, I used the STATA statistical software package to conduct a preliminary analysis of the data to determine the distribution of claims among type and content (Figure 1, Figure 2). The types of claims were split roughly evenly between Section 2 cases, Section 5 cases, and MIR-induced changes. With respect to the content of each claim, nearly half of the claims were either challenges to at-large elections or to a proposed districting plan, while a quarter of the remaining claims were distributed across several categories.

Next, using STATA, I graphed the number of claims for Section 2 and Section 5 by year. By cross-referencing the number of claims by year with key events in the VRA's litigation history, I found that the number and types of claims made under the VRA were highly responsive to significant legislative events and federal voting rights cases. Figure 1 shows the graph of claims by year for Section 2 of the act.

Though Section 2 of the VRA became law in 1965, there was very little Section 2 activity until the early 1980s. In 1982, during the act's renewal, Congress amended the section to make it easier for plaintiffs to win cases. According to a plurality of the Supreme Court in the 1980 case of *City of Mobile v. Bolden*, plaintiffs could only win a Section 2 case if they could prove that the policy at the center of the lawsuit was implemented with an intent to discriminate against minorities. After the 1982 renewal, however, a plaintiff only needed to prove that the policy in question had a discriminatory effect, a standard which made it much easier for plaintiffs to win.[3]

As shown in Figure 3, the 1982 amendment was followed by a massive increase in the number of claims made under Section 2—the number skyrocketed from seven to sixteen. Two years later, during the next major election year, there were 61 cases filed. The next major development took place in 1986, when the Supreme Court affirmed the constitutionality of Section 2 in *Thornburg v. Gingles*. Following that ruling, the number of cases filed under Section 2 skyrocketed yet again. In 1986, there was a record 238 cases filed under Section 2.

We can see similar trends for Section 5 objections (Figure 4). First, there was a sharp increase in objections following the Supreme Court's 1969 decision in *Allen v. Board of Elections*. In *Allen,* the Supreme Court held that Section 5 covers not only changes specifically involving the act of voting itself, but also changes to election structures – such as at-large elections, annexations, and redistricting.[4] Next, there was a large increase of objections in 1975 after Texas was added to the list of areas subject to preclearance requirements. Finally, there was a sharp decrease in objections after the Supreme Court held in *Shaw v. Reno* and *Miller v. Johnson* that racial gerrymandering could not be used to assist minority voters (1993, 1995).

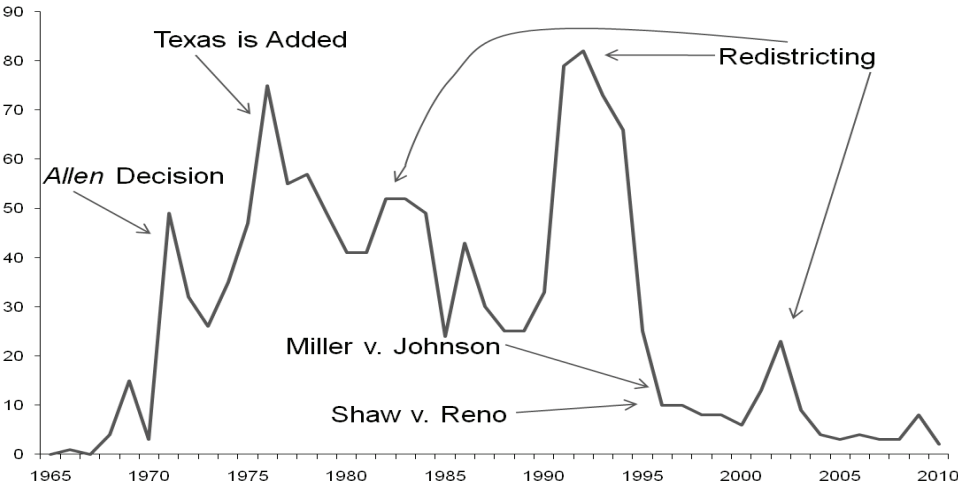


Fig. 4 Section 5 objections follow similar trends to those seen for Section 2. The Supreme Court's 1969 decision in *Allen v. Board of Election*s, in which the Court held that Section 5 covers not only changes specifically involving the act of voting, but also changes to election structures, caused a sharp increase in objections. The next large increase was seen in 1975 after Texas was added to the list of areas subject to preclearance requirements. Finally, there was a sharp decrease in objections after the Supreme Court held in *Shaw v. Reno* and *Miller v. Johnson* that racial gerrymandering could not be used to assist minority voters.

Litigated and Non-Litigated Success

Although the VRA enabled many minorities to challenge discriminatory election policies successfully in court, a staggering number of discriminatory voting rights policies have been altered, repealed, or replaced outside the judicial process because of the VRA. In the extended database, these NLSs came about in three ways: from Section 5 Objections, from MIR-induced

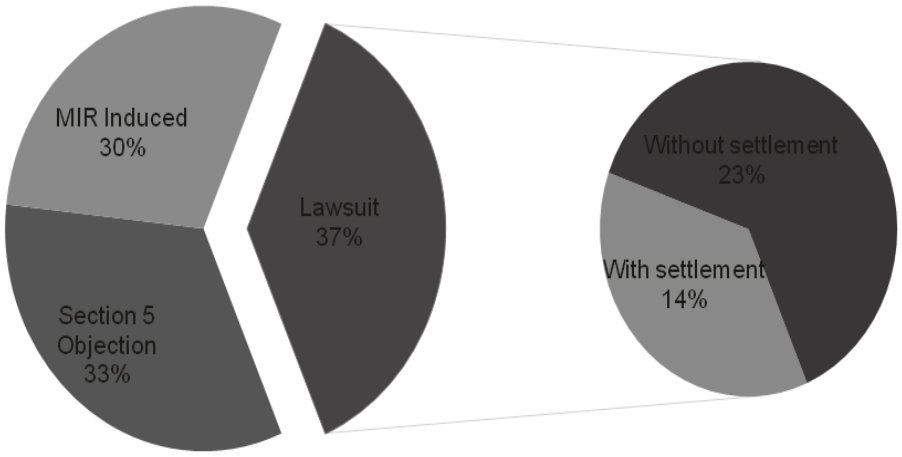


Fig. 5 Distribution of non-litigated successes

changes and legal settlements. Chart 1 in Appendix D shows the distribution of successes. Of all the successful events in the database, 2,164 were NLSs, representing 62% of all successful claims in the database. Figure 6 shows the density of MIR-induced changes by location while Figure 7 shows the density of settlements. The largest cluster of settlements lies in Alabama. Most of those settlements came from just one case—*Dillard v. Crenshaw.* After *Dillard*, 180 jurisdictions with similar election systems agreed to settle rather than go to court. *Dillard* is an example of how the VRA can lead to NLSs. By allowing plaintiffs to succeed in court, the Voting Right Act allows minorities to affect policy without going to court. The fear of litigation as well as the high prospects of failure influence jurisdictions to change their policies without resorting to courtroom battles.

The extent to which the Voting Rights Act leads to Non-Litigated Successes can also be seen through the patterns surrounding MIR-induced changes. According to an unpaired t-test with significance level $\alpha = 0.05$, among areas with a similar number of MIRs, jurisdictions with at least one Section 5 objection were more likely to have MIR-induced changes than jurisdictions without any Section 5 objections. This makes sense—having received an objection, a jurisdiction would take extra care to avoid subsequent objections, and as such, they would be more responsive to MIRs. This trend shows another way in which the VRA influences jurisdictions to implement just election policies. Just as with legal settlements, the desire to avoid legal action causes jurisdictions to implement better policies of their own accord, without formal legal action.

Conclusion

Though the database contains thousands of litigated and non-litigated successes, it does not illustrate the full impact the VRA has on the construction of voting rights policy. Despite the large number of events included in the database, there are many events which will never be included in the database—there are events without paper trails, events which take place behind closed doors, in informal conversations, or even in the minds of policy makers and political operatives. These events are the true non-litigated successes—they are the policies which are cast aside, rejected before they are even proposed or, in many instances, before they enter conscious thought. The true success of the Voting Rights Act lies not with the cases in the database, but rather in the cases that don't exist because of the cases in the database. Though discriminatory policies still exist, the Voting Rights Act, as well as the litigation and oversight mechanisms it created, changed the paradigm of thought among policy makers in local jurisdictions. Discriminatory policies that were once acceptable and commonplace don't even enter the minds of policy makers. Still other policies are rejected immediately because of their discriminatory nature and inevitable failure. It is these cases, along with the powerful cases and events included in the database, which demonstrate the true power and potential of the Voting Rights Act.

Finally, while the Voting Rights Act has so far managed to outlast its critics, the entries in the database show that the future success of the Voting Rights Act is not guaranteed. To the contrary, the act has been and remains fragile. Accordingly, we see that supporters of the act must continue working to defend the act and to push for the continued support of Congress and the courts so that the act can continue to protect the rights of minorities and to maintain the integrity of America's democracy.

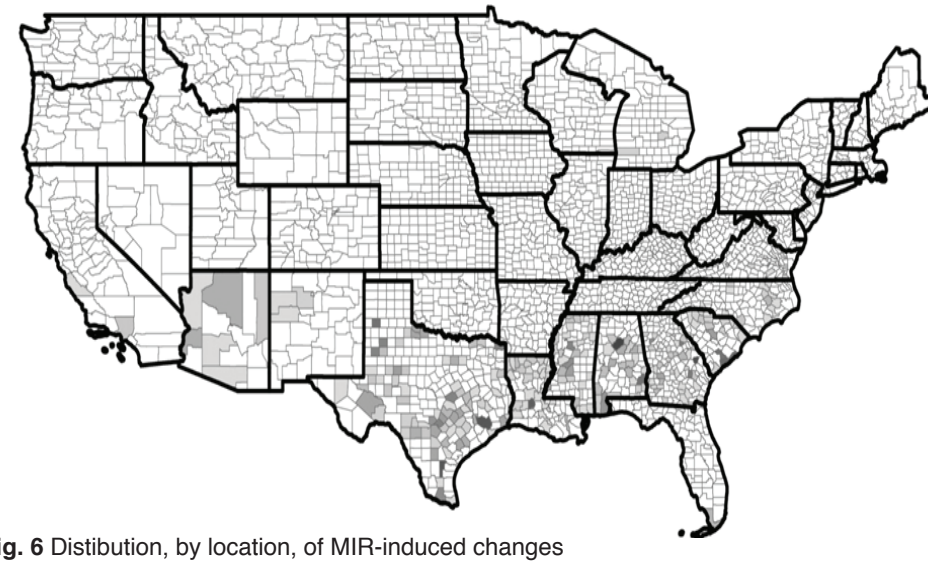


Fig. 6 Distibution, by location, of MIR-induced changes

Future Studies

Though I added many cases to the database, there are still many more events to track down and enter. Private litigation files, older scholarly works, additional MIR records, and a variety of other sources would, if added to the database, shed a lot of additional light on how the VRA functions. In addition to finding more sources of data, the database can be used to answer many questions which this study did not address. How have private lawyers affected the nature of voting rights litigation? Have private attorneys contributed to the increase and decrease of cases filed by the

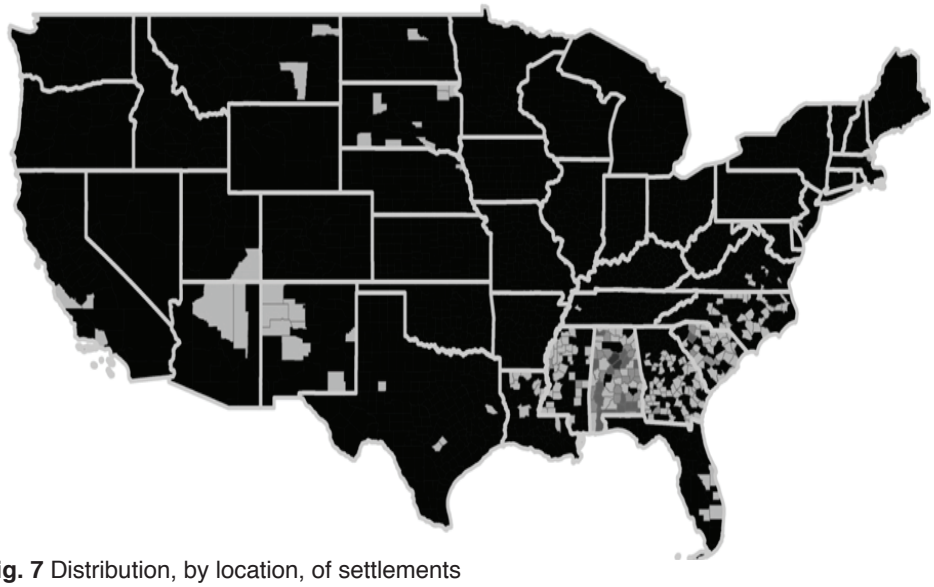


Fig. 7 Distribution, by location, of settlements

DOJ? What factors make a case more likely to trigger settlements? Why was *Dillard* v. *Crenshaw* so successful? These and a variety of other questions can be answered with the database.

Notes

1. For the first several years after its passage, Section 5 of the Voting Rights Act was largely ignored by covered jurisdictions (Kousser 685).
2. For the purposes of this paper, an NLS is an MIR-induced change or VRA related settlement.
3. Senate Report 417(1982) contended that the *Bolden* plurality had misconstrued congressional intent, and that Section 2 had always been meant to ban laws or practices with a discriminatory effect, and further, that Congress had the power under the constitution to ban laws or practices with a discriminatory effect.
4. Direct changes in voting regulation include changes which implement policies which prevent minorities from voting such as poll taxes, literacy tests, or residency requirements. Structural changes allowed by the *Allen* decision include changes such as redistricting or staggered terms—changes which decrease the effectiveness of minority votes.

References

1. Allen v. State Board of Elections, 393 US 544. 1969.
2. City of Mobile v. Bolden, 446 US 55. 1980.
3. Kousser, Morgan. Colorblind Injustice, 1999.
4. Kousser, Morgan. "The Strange, Ironic Career of Section 5 of the Voting Rights Act, 1965-2007," Texas Law Review, Volume 86, No. 4, March 2008.
5. Miller v. Johnson, 515 US 900. 1995.
6. NAMUDNO v. Holder, 557 U.S. Supreme Court of the United States. 2009. http://supreme.justia.com/us/557/08-322/opinion.html
7. Petitioner's brief in NAMUDNO, http://electionlawblog.org/archives/namudno-appellants-brief.pdf
8. Pildes, Richard. "A Warning to Congress," 28 June, 2009. http://roomfordebate.blogs.nytimes.com/2009/06/22/the-battle-not-the-war-on-voting-rights/
9. Shaw v. Reno, 509 US 630. 1993.
10. Thornburg v. Gingles, 478 US 30. 1986.

Adam Adler is a member of the Class of 2012 majoring in Mathematical and Computational Science. His interests include Number Theory and Constitutional Law, and Jurimetrics (the application of Math and Statistics to the Judiciary). Adam also enjoys writing satire and is the editor of Stanford's satirical newsletter, The Stanford Flipside.

Identities claimed, identities assigned: Transgender subjectivities in Raymond's *The Transsexual Empire* and Stone's *The Empire Strikes Back*

Charles Syms

In attempts to understand gender, whether by feminist scholars, sociologists, or biologists, the very identities through which transgender individuals situate their lives become continual sites of dispute. Through investigating the way in which various spaces in the academy and professional world employ power hierarchies to strip transgender people of agency in identity, it is possible to not only highlight the injustice but also to encourage change. With examples from sociology, biology and medicine, law, feminist theory, popular culture and the media, this essay addresses the ways in which transgender subjectivities are regulated by supposed authorities without consideration of transgender perspectives. Particularly concerned with the tensions between feminist and queer theory, this essay analyzes how arguments that essentialize gender are at once employed and denied in an attempt to establish a monolithic, exclusive category of "women." By exploring the various spaces that occupy the realm of transgender identity, from pre-surgical transsexuals to genderqueer individuals, this essay outlines the ways in which external power structures have been used to subjugate and categorize transgender bodies and provides suggestions for how transgender subjectivity can be reclaimed by transpositive activists.

Identity, at once a regulatory force and a potential source of empowerment, is a multifaceted element of the human experience. Not only does identity change with time, geographical and cultural surroundings, and cognitive development, it also has a major role in legitimizing the experiences of some while falsifying the experiences of others. Transgender individuals—those who identify with or express a gender identity that differs from the one which corresponds to their sex at birth are a minority within the lesbian, gay, bisexual, and transgender community. Thus, they are often stripped of agency when it comes to their identities. Through dismissal of preferred pronouns, discrediting based on the classification of transsexualism as a mental illness, and arbitrary claims about what makes an authentic woman or man, academics and medical professionals ensure that "the people who have no voice in this theorizing [of the transsexual] are the transsexuals themselves" (Stone, Sandy 294).

The feminist movement has a very complicated relationship with the emerging prominence of transgender identities. As an ideology that calls into question the prescribed roles of men and women in society, it seems probable that feminism would embrace the physical transgressing of genders by transgender individuals with open arms. This, however, does not prove to be the case for many feminists. In her book *The Transsexual Empire*, Janice Raymond makes it very clear that she does not see transsexualism as being in line with feminist ideals. Claiming that it "should not be surprising that men, who have literally and figuratively, constructed women for centuries, are now 'perfecting' the man-made women out of their own flesh," Raymond asserts that male-to-female transsexuals—those who were born male and are in the process of becoming a woman, also known as transwomen—are not able to transgress their biological sex (Raymond xv). According to Raymond, biological men will always be men, no matter what clothing they wear, hormones they take, or surgery they undergo. In fact, Raymond goes as far as to call them "male-to-constructed-female transsexuals," denying male-to-female transsexuals the right to claim a fully female identity (Raymond xiii). Are not all females constructed in some way? Indeed, feminist theory has a long tradition of challenging essentialist conceptions of womanhood that are employed to limit women to the domestic sphere. If, as Simone de Beauvoir states in *The Second Sex*, "[o]ne is not born, but rather becomes, a woman," then it is possible to understand a transwoman's process of becoming a woman given the socially constructed nature of the term (de Beauvoir 267). The assertion that male-to-female transsexuals cannot fully become women denies transwomen of—and privileges ciswomen with—the capacity to be authentically female. (Cisgender is an adjective used to describe someone who identifies with the gender assigned to him or her at birth based on biological characteristics. Thus, ciswomen are biological females who also identify as women.)

The conflation of the terms "female" and "woman" in Raymond's argument is a critical flaw that must be explored. Biological sex, which is assigned at birth, needs to be distinguished from gender, a socially constructed set of roles that are binary in most western cultures. For example, a biological male might not be able to change the chromosomes that make him XY, but he can certainly take on the cultural and physical traits that are associated with women in his society.

Though many parts of Raymond's argument are disempowering to transsexual individuals, she does raise a valid question of exactly what kind of impact transsexualism has on gender norms in society. She highlights that "[p]ersons who think they are of the opposite sex are…not encouraged to see this as emanating from the social constraints of masculine and feminine role-defined behavior," reminding her audience that gendered categories are social constructs (Raymond xvii). Indeed, if all gender roles are socially constructed, how does one justify physically altering one's body to have it align with a socially prescribed set of norms? And while the point Raymond makes is valid, the implied critique is not: Raymond should not expect transsexuals to challenge gender roles any more than people whose biological gender aligns with their gender identity.

Raymond sees the emphasis placed on authentically masculine and feminine gender roles as the problem: "Ultimately transsexual surgery reinforces social conformity by encouraging the individual to become an agreeable participant in a role-defined society, by substituting one sex role stereotype for the other" (Raymond xvii). In her view, simply switching from one side of the binary to the other does not radically alter the oppressive gender hierarchy—instead, it reinforces the hierarchy while refraining from questioning it. Although this is a valid critique of transsexual identities, it is also one that does not incorporate the realities of the transsexual experience. Having one's gender identity be unaligned with one's gender presentation can be an incredibly isolating feeling, and openly transgressing gendered norms might be the last goal for someone who is trying to pass as the other gender. In fact, it is Raymond's firmly established and socially recognized position as a woman that allows her to critique what it means to be a woman in the first place.

Throughout *The Transsexual Empire*, Raymond places a large emphasis on the definition of a "real" woman. According to Raymond, the fact that male-to-female transsexuals were born male is enough to discount them from the category of "real" women. In explaining why she believes this, Raymond turns to an essentialist concept of "[a] female reality that the surgically-constructed woman does not possess" (Raymond xx). Invoking imagery of motherhood and menstrual cycles, Raymond binds femaleness to womanhood in a way that excludes those without biologically female experiences from being included in the elusive category of "real" women. Regardless of how a male-to-female transsexual might identify, Raymond denies the male-to-female transsexual the right to have an authentic woman identity. Thus, Raymond is removing the agency from the transsexual individual and imposing her view of what makes a "real" woman as the criterion by which all women should be judged.

With her harsh view of transsexualism, Raymond serves to position her notion of feminism in opposition to a transsexual identity. Raymond argues that "transsexualism constitutes a sociopolitical program that is undercutting the movement to eradicate sex-role stereotyping and oppression in this culture," invoking the image that transsexuals represent everything that feminists stand against (Raymond xxi). In positioning transsexualism and feminism as opposites, Raymond discounts the possibility that transsexuals might identify as feminists and visualize their transsexualism as an expression of a feminist desire to challenge traditional roles for men and women. Once again, Raymond ensures that the transsexual is assigned intent, regardless of whether or not that intent matches up with how the transsexual might see his or her goals in transitioning between genders.

Raymond also problematically imposes her idea of the transsexual's objective in transitioning. Claiming that "many men [flock] to hormones and surgery to attract other men as artifactual, ultrafeminine women," Raymond completely discounts the possibility that a trans-identified person might decide to undergo the dramatic changes that come with hormonal therapy or gender reassignment surgery for himself or herself (Raymond xxvi). In this view, the transsexual is defined in terms of another person, which is as problematic as the antiquated notion that wives should be the property of their husbands. As long as Raymond continues to define the transsexual's intent in relation to others, she strips the transsexual of authority when it comes to his or her aspirations.

In addition to her unjustified assumptions of transsexual desires, Raymond refuses to recognize the preferred pronouns of the transsexual subjects she mentions in her work. When referring to her academic peer Sandy Stone, Raymond writes, "Stone has gotten himself a thorough postmodernist education," completely disregarding the fact that Stone identifies as a woman (Raymond xxii). Not only is this disrespectful, it reveals a very telling part of Raymond's belief that she should have the authority to determine who can use which pronouns. Raymond is not just casually using the incorrect pronoun—she is issuing a clear statement to her colleague Stone that she is not a true woman.

As an alternative to Raymond's regulation of transsexual identities, Sandy Stone attempts to empower the voices of transsexuals in her rebuttal text entitled *The Empire Strikes Back*. Instead of relying on her own personal idea of what transsexuals should desire or experience, Stone employs the lived experiences of actual transsexuals in the formation of her argument.

Stone touches on an interesting point of the contention around the exact moment when a transsexual person changes genders. Though some transsexuals might say there is no definitive moment, Stone gives the example of Hedy Jo Star, who testifies in reference to her gender reassignment surgery, "'the instant that I awoke from the anesthetic, I realized that I had finally become a woman'" (Stone, Sandy 286). By citing Star's experience alongside several dissenting viewpoints, Stone acknowledges that there is no one universal moment of transsexual experience that dictates when one has officially transitioned genders. In contrast to Raymond, who imposes her view of transsexual experience on transsexuals, Stone addresses that there is no monolithic trajectory of a transsexual life and thus empowers transsexual subjectivity.

In order to explain how agency to construct one's own identity is taken away from transsexuals, Stone employs an extremely powerful metaphor. She describes, "[b]odies are screens on which we see projected the momentary settlements that emerge from ongoing struggles over beliefs and practices within the academic and medical communities" (Stone, Sandy 294). Much like the way in which a women's right to make decisions about her reproductive health is debated by male politicians, doctors and professors are waging the war of legitimacy in identity on the battlefield of transsexual bodies. This metaphor invokes the concept of transsexuals serving as experimental subjects for the academic and medical professionals who are in the authoritative positions to decide if and in what way transsexual people are able to construct their identities. It also ensures the reinforcement of the gender binary, as transsexuals are expected to "pass" as the opposite sex in order to be suitable candidates for gender reassignment surgery. Essentially, transsexuals are coerced into a rigid set of possible identities and risk disqualification for medical treatment if they stray from what the people in power have determined is correct for them.

Acknowledging the detrimental effect that imposed identities can have on trans-identified individuals, Stone reaches out to "the brothers, sisters, and all others who may read [her essay]" and implores them to "use the strength which brought [them] through the effort of restructuring identity, and which has also helped [them] to live in silence and denial, for a re-visioning of [their] lives" (Stone, Sandy 299). Stone directly addresses the people who

are constantly being theorized about, illustrating how she is aware that transsexuals are humans just like everybody else. Raymond, on the other hand, seems to forget (or trivialize) this point. Though openness about transsexuality will not mandate societal acceptance, Stone understands that the more people know about transsexuality, the less they will be able to claim ignorance and justify the identities they impose on such a diverse group of people.

To position Raymond and Stone's arguments within the broader dialogue about transgender subjectivity, it is important to explore real-world examples of the ways in which transgender identities are either claimed or assigned. In an article about transmen—those who were born female and are in the process of becoming a man, also known as female-to-male transsexuals—and their interactions with the gay male community, Shawn Syms quotes a transmen who articulates, "it's a common assumption that because they aren't born with penises [that] all trans guys must be bottoms" (Syms 14). Within a community united on the premise of claiming non-heteronomative sexual roles-—those not of or pertaining to the practices and institutions that legitimize and privilege heterosexuality, heterosexual relationships, and traditional gender roles as fundamental and natural within society—it might seem surprising that assumptions are made about the sexual roles of others. This assumption, however, mirrors the decisions made by Raymond about who can claim which identities, and illustrates that no community is immune to the idea that the identities of others, particularly those who are transgender, can be determined by another group.

Another dimension through which to look at Raymond and Stone's opposing viewpoints is the legal implication of identities. In the case of child custody and marital law, "judges use a 'body-parts checklist' to determine what sex transsexuals are, using these decisions to invalidate marriages and make transgender parents 'legal strangers' to their own children" (Stone, Amy 592). Thus, it is evident that the ability of outsiders to designate identities for transsexuals has far reaching implications, including the possibility of denying a transsexual parent the right to see his or her children. The power of the law to essentialize gender to an inventory of one's body parts creates a dynamic where transsexuals are pressured to have their gender presentation conform to their anatomical sex in order to avoid accusations of illegitimacy.

Perhaps one of the most concrete examples of the problems inherent in assigning identities is evident in the case of Brandon Teena. A female-to-male transsexual murdered in Nebraska, Teena was subjected to the questioning of his male identity by feminist observers of his case. Rather than respecting Teena's desire to be recognized as a man, "[s]ome feminists have understood Brandon as a transgressive woman who performed gender and sexuality as a continuum of practices and behaviors rather than a fixed identity" (Eileraas 92). As he is unable to claim his male identity after his death, Teena's identity becomes "a site of contest" for the media, and subsequently a "war over gender pronouns [plays] out in media reports of Brandon Teena's murder and psychological assessments of his gender identity" (Eileraas 96). Teena's murder epitomizes the silencing that transsexuals face concerning their identities, and the projection of identity onto Teena from feminist observers underscores the way in which Teena's desired gender recognition is disregarded in favor of a personal opinion of his gender identity.

The ultimate way in which this contestation of Teena's identity unfolds is on his tombstone. Asserting that "Teena R. Brandon" was a "daughter, sister, and friend," his grave marker imposes an eternal female representation on Earth ("Photograph of Teena Brandon's Grave"). Though arguably the expert on his own gender identity, Teena and his desire to be recognized as male are both disregarded, and a female gender is assigned to him because he was not intersex—that is, he did not possess both male and female sexual characteristics and organs—nor was he taking hormones (Eileraas 94). Teena's grave exemplifies the way in which transsexual gender identities are contested, rewritten or ignored without regard to the transsexual's voice.

Though it has been almost twenty years since Raymond and Stone published the most recent editions of their academic discussion of transgender identities, it is important to note that the dialogue surrounding the legitimacy of transgender identities continues to take place in academia. Most recently, at the 2010 "Pornography as Sexual Violence" conference at the University of New Hampshire, the same contentions evident between Raymond and Stone resurfaced to become a major debate throughout the entire conference. In the words of Joelle Ryan, a transgender woman who presented at the conference, the lack of a productive dialogue surrounding transgender identities proves that the "sex wars détente continues unabated" (Ryan). At one point during the conference, Ryan found her transgender identity the target of criticism when another conference participant "[launched] into a full frontal attack on [her] as a transgender person." The same tactics of critiquing and silencing transgender individuals while assuming an authoritative position on the topic of transgender identity illustrates how a battle based on identity politics continues to play out on the battleground of transgender bodies. Rather than being outdated after a few decades of slowly but steadily increasing acceptance of transgender individuals, the anti-trans dialogue started by Raymond and challenged by Stone continues to shape contemporary academic discourse surrounding transgender identities. The perseverance of these contentions suggests that the continued regulation of transgender identities and the imposition of the resulting conclusions are occurring entirely outside of the transgender community's sphere of influence.

Given the severe discrimination transgender people face, it is an incredible risk to claim a transgender identity in our society. This is further complicated by the fact that doctors, professors, judges, gay men, feminists, and many other groups feel compelled to designate who can claim what kind of gender identity. In understanding transgender identities, it is essential to pay attention to the way in which non-trans-identified people can deny the voices of transgender people from being heard. As Stone suggests, "[p]erhaps it's time to begin laying the groundwork for the next generation"—a generation in which transgender people are the locus of authority when it comes to their own identities (Stone, Sandy 299).

References
1. de Beauvoir, Simone. The Second Sex (1949).
2. Eileraas, Karina. "The Brandon Teena Story: Rethinking the Body, Gender Identity, and Violence Against Women." Michigan Feminist Studies (2002): 85-116.
3. Monro, Surya. "Beyond Male and Female: Poststructuralism and the Spectrum of Gender." International Journal of Transgenderism (2005): 3-22.
4. "Photograph of Teena Brandon's Grave." FindAGrave.com. Web. 16 Mar 2009.
Raymond, Janice. The Transsexual Empire (1994).
5. Ryan, Joelle. "Bob Jensen, Lierre Keith *et al.*: The Rabid, Transphobic Hate-Mongering of the Anti-Pornography Movement."
6. Transmeditations. 23 Oct 2010. Web. 7 Feb 2011.
7. Syms, Shawn. "Trans Men Loving Gay Men Loving Trans Men." Capital Extra Ottawa (2007): 14-15.
8. Stone, Amy L. "Changing Transgender Politics." GLQ: A Journal of Lesbian & Gay Studies (2007): 592-594.
9. Stone, Sandy. "The Empire Strikes Back: A Posttranssexual Manifesto." Body Guards (1991): 280-304.

Charles Syms is a senior from San Antonio, Texas, majoring in East Asian Studies and Feminist Studies. He is also pursuing a co-terminal Masters degree in Sociology. His honors thesis investigates contentions within the Korean LGBTQ rights movement and the impact they will have on the future of Korea's queer rights movement. Upon graduation, Charles anticipates working in the non-profit sector for a few years before contemplating additional graduate education.

Single document text summarization using Random Indexing and Neural Networks

Avikant Bhardwaj (India Institute of Technology, Delhi)

This paper presents a new extraction-based summarization technique developed using neural networks and Random Indexing. The technique exploits the advantages that a neural network provides in terms of compatibility and adaptability of a system to the user. A neural network is trained to recognize the important properties of sentences that should be included in the summary. The trained neural network is then used as a sieve to filter out the sentences relevant for a corresponding summary. The neural network, along with Random Indexing, extracts the semantic similarity between sentences in order to remove redundancy from the text with high accuracy. One major advantage of the proposed scheme is that it also takes into account human subjectivity.

Automatic text summarization has become an important tool for interpreting text information, due to the increased usage of the internet and the abundance of knowledge in textual form available on the World Wide Web. However the internet usually provides more information than is needed. Hence, extracting useful summaries from a large body of relevant information has become a major focus of research in Natural Language Processing (Kaikhah, 2004).

The prime focus of the present work is to generate an extractive summary of a single document using neural networks. The basic difficulty seen in summarization is that the quality of the summary is subjective; almost all the current techniques ignore this property. However, our intuition is that by using Neural Networks (NN) we can generate summaries which are much closer to human extracted summaries, as they are trained on available standard human summaries to produce a better result. In this work we have combined NN and Random Indexing (Sahlgren, 2005) obtaining significant improvements over commercially available summarizing tools.

Traditional extractive summarization techniques are typically based on simple heuristic features of the sentences. Though there has been considerable and thorough research work on graph-based or other implementations of text summarizers, there has not been much work using Artificial Intelligence techniques in general, and neural networks in particular, except for some heuristic approaches.[1] Researchers have tried to integrate machine learning techniques into summarization with various features, such as sentence length cut-off, fixed-phrase, thematic word, and many more (Kupiec *et al*., 1995). Additionally, some commercially available extractive summarizers like Copernic[2] and Microsoft Office Word summarizer[3] use certain statistical algorithms to create a list of important concepts and hence generate a summary.

This paper is organized as follows. Section 1 describes neural networks and the Backpropagation algorithm. Section 2 explains the technique of Random Indexing. Sections 3 and 4 discuss the experimental set-ups and the results obtained, respectively. In Section 5 we conclude the paper.

1. Neural Networks

An Artificial Neural Network (ANN) is a mathematical or computational model that tries to simulate the structure and/or the functional aspects of biological neural networks. Neural networks are non-linear statistical data modeling tools and are used to model complex relationships between inputs and outputs and to find patterns in data (Rojas, 1996). The artificial neurons, constitutive units in an ANN, are mathematical functions observed as a rudimentary model, or abstraction, of biological neurons. Mathematically, let there be n + 1 inputs with signals x_0 to x_n and weights w_0 to w_n, respectively. Usually, the x_0 input is assigned the value +1, which makes it a bias input with $w_0 = b$. This leaves only n actual inputs to the neuron: from x_1 to x_n. The output of such a neuron is (where φ is the activation function):

$$y = \varphi\left(\sum_{j=0}^{n} w_j x_j\right) \qquad (1)$$

In the "learning" phase of a neural network, we try to find the best approximations of the different weights $w_0, w_1,...,w_n$. This is done by minimizing a cost function, which gives a measure of the distance between a particular solution and the optimal solution. Numerous algorithms are available for training neural network models (Bishop, 2005); most of them can be viewed as a straightforward application of optimization theory and statistical estimation. We have implemented one of the more popular learning algorithms, the Backpropagation algorithm. This algorithm involves interative supervised learning, in which the error produced in each iteration is used to improve the weight assigned to each input variable, forcing the output value to converge to the known value.[4]

In order to use a neural network approach, we first require that the sentences are in some mathematical model so that we can use them as input in our network. For that purpose, we introduce Word Space Modeling, a spatial representation of word meaning, through Random Indexing (RI) (Chatterjee and Mohan, 2007). RI transforms every sentence into a vector location in word space and NN then uses that vector as input for computational purposes.

2. Word-Space Model

The Word-Space Model (Sahlgren, 2006) is a spatial representation of word meaning. It associates a vector with each word, defining its meaning. However, the Word Space Model is based entirely on language data available. When meanings change, disappear, or appear in the data at hand, the model changes accordingly. The primary problem with this representation is that we have no control over the dimension of the vectors. Consequently, use of such a representation scheme in NN-based model is not appropriate. We use a Random Indexing based representation scheme to deal with this problem.

2.1 Random Indexing Technique

The Random Indexing technique was developed to tackle the problem of high dimensionality in the Word Space Model. It removes the need for a huge co-occurrence matrix by incrementally accumulating context vectors, which can then, if needed, be assembled into a co-occurrence matrix (Kanerva, 1988).

In Random Indexing, each word in the text is assigned a unique and randomly generated vector called the *index vector*. All the index vectors are of the same predefined dimension R, where R is typi-

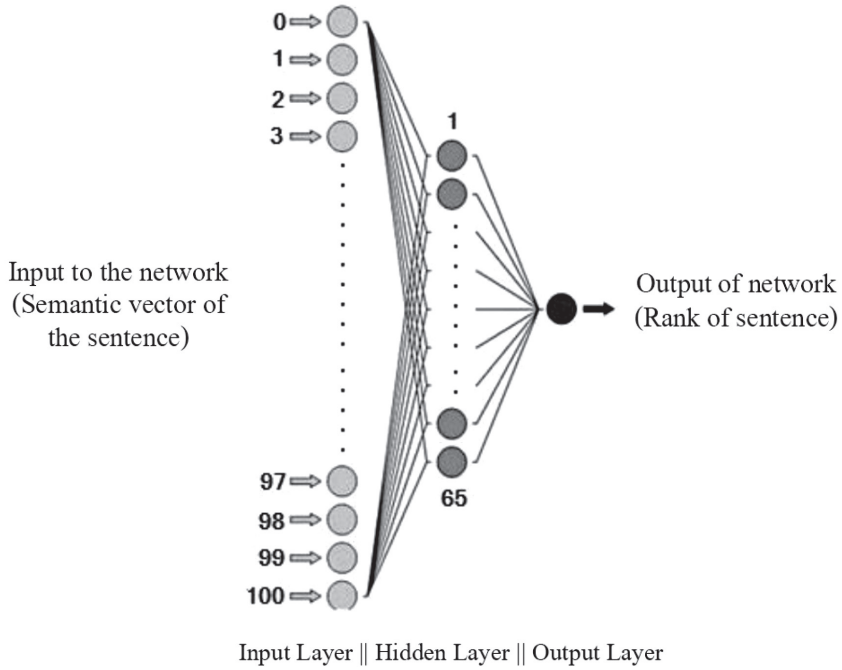


Fig. 1 A schematic diagram of the neural network

cally a large number, but much smaller than n, the number of words in the document. The index vectors are generally sparse and ternary (*i.e.* they are made of three values chosen from the set {0, 1, −1}, with most of the values 0). When the entire data has been processed, the R-dimensional context vectors are effectively the sum of the words' contexts. For illustration, we can take the example of the sentence:

An eye for an eye makes the whole world go blind.

Let, for example, the dimension R of the index vector be 10. The context is defined as one preceding and one succeeding word. Let 'whole' be assigned a random index vector: [0,0,0,1,0,0,0,0,−1,0] and 'makes' be assigned a random index vector: [0, 1,0,0,0,0,0,0,0,−1]. Then to compute the context vector of 'world' we need to sum up the index vector of its context which is, [0,1,0,1,0,0,0,0,−1,−1]. The space spanned by the context vectors can be represented by a matrix of order $W \times R$, where i^{th} row is the context vector of i^{th} distinct word.

If a co-occurrence matrix has to be constructed, R-dimensional context vectors can be collected into a matrix of order $W \times R$, where W is the number of unique word types, and R is the chosen dimensionality for each word. Note that this is similar to constructing an n-dimensional unary context vector which has a single 1 in different positions for different words where n is the number of distinct words. Mathematically, these n-dimensional unary vectors are orthogonal, whereas the R-dimensional random index vectors are nearly orthogonal. However, most often this does not stand in the way of effective computation. On the contrary, this small compromise gives us huge computational advantage, as explained below. There are many more nearly orthogonal directions than truly orthogonal directions in a high-dimensional space (Sahlgren, 2005). Choosing Random Indexing is an advantageous trade-off between the number of dimensions and orthogonality, as the R-dimensional random index vectors can be seen as approximations of the n-dimensional unary vectors.

2.2 Assigning Semantic Vectors to Documents

The average term vector can be considered the central theme of the document and is computed as:

$$\vec{x}_{mean} = \frac{1}{n}\sum_{i=0}^{n}\vec{x}_i \qquad (2)$$

where n is the number of distinct words in the document. When we compute the semantic vectors for the sentences, we subtract x_{mean} from the context vectors of the words of the sentence to remove bias from the system (Higgins *et al*., 2004). The semantic vector of a sentence is thus computed as:

$$\vec{x}_{semantic} = \frac{1}{m}\sum_{i=0}^{m}(\vec{x}_i - \vec{x}_{mean}) \qquad (3)$$

where m is the number of words in the focus sentence and x_i refers to the context vector of the i^{th} word. Note that subtracting the mean vector reduces the magnitude of those term vectors which are close in direction to the mean vector, and increases the magnitude of term vectors which are most nearly opposite in direction from the mean vector. Thus the words that occur very commonly in a text, such as auxiliary verbs and articles, will have little influence on the sentence vector which is produced. Further, the terms whose distribution is most distinctive will be given the maximum weight. The semantic vector of the sentence thus obtained and is fed into the NN as input vector, and the corresponding output from the NN is the ranking of the sentence, which is a real number between 0 and 1.

3. Experimental Set Up

Our experimental data set consists of 25 documents each containing between 300 and 700 words. The processing of each document to generate a summary has been carried out as follows:

3.1 Mapping of Words on Word Space Model

We have implemented the mapping of words onto the word space by three methods, namely the Narrow Window Approach, Extended Window Approach and Sentence Context Approach. In the 'narrow window' approach, each word in the document was initially assigned a unique randomly generated index vector of dimension 100 with ternary values from {0, 1, −1}. The index vectors were constructed such that each vector of 100 units contained two randomly placed 1 and two randomly placed −1s, and the rest of the units were assigned a value of 0. Each word was also assigned an initially empty context vector of dimension 100. We defined the context by a 2 × 2 sliding window on the focus word. The context of a given word was also restricted to one sentence, so windows which spanned sentences were not considered. Experiments conducted at SICS, Sweden (Karlgren and Sahlgren, 2001) have indicated that a 2 × 2 window is preferable for acquiring semantic information. Once context vectors for words are generated, we then generate semantic vectors for individual sentences, as described. The second approach, 'extended window,' considers a sliding window of

size 4 × 4 rather than 2 × 2. Thus the problem with the kind of words that have the same immediate context words but different meanings is resolved by taking a larger window. For example, consider the two sentences *Doing good is humane* and *Doing bad is inhumane*. Here, *good* and *bad* have same immediate context words but have different meanings. However, if we extend the window for context words, then we will have a much better approximation of their meanings. In the third approach of 'sentence context,' we have updated the input vectors not from the semantic vectors of sentences, but by realizing the semantic vectors as context vectors for sentences, and hence created the input vector by adding the 4×4 context window's context vectors.

We now have the semantic vectors of the sentences of the document, which act as the input pattern vectors for our neural network. The sentence is selected or rejected on the basis of the output given by the network for the corresponding semantic vector.

3.2 Text Summarization Process

The proposed approach summarizes given text documents through a two-phase process. The first step involves a one time training of a neural network through change in its weights to recognize the type of sentences that should be included in the summary. Once training is done, any number of single document text files can be summarized in the second step, which uses the modified neural network from the first stepto sieve the text in order to select only the highly ranked sentences and create the required summary.

3.2.1 Training of the Neural Network

The first phase of the summarization process involves training the neural networks to learn the types of sentences that should be included in the summary. This is accomplished by training the network with sentences in several test paragraphs where each sentence is identified as included in the summary or not. For this purpose, the training texts and the corresponding summaries are provided by the user all in separate text files after appropriate pre-processing, such as formatting the text such that every sentence starts on a new line and there are no blank lines in between, etc. The neural network learns the patterns inherent in sentences should and should not be included in the summary. Note that we use a Feed-Forward neural network, which is considered a universal function approximator and is very efficient in discovering patterns and approximating the inherent function.

Figure 1 shows the structure of the neural network used in this work. As shown, the network contains three layers: the Input Layer, a single Hidden Layer and the Output Layer. The output layer of our network contains only one neuron whose output gives the rank of a sentence on the basis of which the sentence is selected or rejected. However, the number of neurons in the input layer of our network is 101 (one for the bias and the remaining for the 100 inputs, each corresponding to one dimension of the index vector) and the number of neurons in the hidden layer is 65. The number of neurons in the hidden layer has been selected arbitrarily. However, it can also be calculated using the following formula:[5]

$$numHid = \frac{numInput}{2} + \sqrt{numPat} \qquad (4)$$

where *numHid* is equal to the number of Hidden layer neurons, *numInput* is equal to the number of inputs including bias and *numPat* is equal to the number of patterns to be trained. The number of hidden layer neurons should not be, in any case, less than the number obtained from above formula, as this leads to an inconsistency in weights updating of larger texts. However, a larger number of neurons will result in slower training. Hence, in order to strike a balance between training time and consistency, we decided to keep 65 neurons in the hidden layer. In our case, the training patterns are the semantic vectors of the sentences of the training documents. The overall error is calculated using the mean squared error of individual error generated by each training pattern. The maximum number of iterations for the algorithm is 10000 and the tolerance limit for the total error has been kept as 0.0000003, which have been found to be optimal by repeated trials. The learning rates for changing the weights between both input-output layers and hidden-output layers are 0.01. The activation function used for the hidden layer's neurons is the sigmoid function; for the output layer's neuron we used a linear function.

3.2.2 Generating a Summary of an Arbitrary Text

Once the network has been trained, it can be used as a tool to filter sentences in any paragraph and determine whether each sentence should be included in the summary. The program finds the semantic vectors of the sentences of a given document. Using the weight values found in the training step, the outputs of the network corresponding to each of these semantic vectors is calculated. This output of a semantic vector corresponds to the rank of the corresponding sentence, which is directly proportional to its priority/importance within the document. The sentences are then sorted using a modified quicksort technique. On the basis of their ranks, the high priority sentences are selected to create the summary. Note that in the present case we are selecting summaries based on the percentage of total number of words in the document. Since it may not give an exact number of sentences, we chose the top few sentences according to their ranks, such that the total word count does not exceed the percentage mentioned, with a margin of 10%. For a specific example, for 25% summaries, we selected top ranked sentences until the total sum approaches 27.5% of the total number of words in the text.

4. Results

We have trained our summarizer on 15 different texts and their standard summary provided by DUC. Each document of DUC 2002 corpus is accompanied by two different abstracts manually created by professional abstractors. For each abstract created with this method, we built a corresponding extract summary by replacing restructured sentences with the closest sentence(s) from the original document. We then took the union of the sentences to obtain a reference summary (S_{ref}). For evaluation, our results have been compared with the reference summary thus created. We ran our experiments on a different set of 10 texts and computed extracts at 25% and 50% levels. We then compared our candidate summary, one from each approach, (denoted by S_{cand}) with the reference summary and computed the precision (p), recall (r) and F values (Yates and Neto, 1999). We also compute the p, r and F values for the summaries generated by Copernic and MS Word summarizers. The values obtained for 10 test documents only (due to space constraints) are shown in Table 1.

Table 1 shows the comparison of the 25% and 50% summaries of 10 randomly selected text files of DUC 2002, outside the training texts. For each of them we computed the p, r and F values for all the three approaches we have proposed, and also for Copernic and MS Word summarizers. Out of the 20 cases, the Sentence Context approach delivered the best results in as many as 13 cases. This was followed by the Extended Window approach, which provided the best results in three tests, while MS

Text No. (Size of text)		Narrow Window p	r	F	Extended Window p	r	F	Sentence Context p	r	F	Copernic p	r	F	MS Word p	r	F
1	25%	0.50	0.50	0.50	0.50	0.75	0.60	**0.75**	**0.80**	**0.77**	0.33	0.60	0.43	0.50	0.50	0.50
(359)	50%	0.38	0.50	0.43	0.43	0.50	0.47	**0.50**	**0.67**	**0.57**	0.43	0.45	0.44	0.25	0.33	0.29
2	25%	1.00	0.50	0.67	**0.83**	**0.70**	**0.76**	0.41	0.44	0.42	0.50	0.67	0.57	0.10	0.50	0.17
(298)	50%	0.50	0.38	0.43	0.55	0.63	0.59	**0.63**	**0.63**	**0.63**	0.50	0.33	0.38	0.50	0.38	0.43
3	25%	0.00	0.00	NaN	**0.78**	**0.78**	**0.78**	0.60	0.67	0.63	0.43	0.60	0.50	0.67	0.50	0.57
(396)	50%	0.50	0.55	0.53	**0.70**	**0.78**	**0.74**	0.67	0.67	0.67	0.57	0.63	0.60	0.33	0.44	0.38
4	25%	0.10	0.40	0.16	0.33	0.30	0.31	**1.00**	**0.89**	**0.93**	0.25	0.50	0.33	0.00	0.00	NaN
(408)	50%	0.38	0.33	0.35	0.63	0.55	0.59	**0.89**	**0.78**	**0.83**	0.33	0.55	0.41	0.25	0.22	0.24
5	25%	0.25	0.25	0.25	0.20	0.40	0.27	**0.80**	**0.67**	**0.73**	0.63	0.50	0.56	0.40	0.50	0.44
(519)	50%	0.50	0.60	0.54	0.50	0.60	0.54	**0.50**	**0.60**	**0.54**	0.40	0.55	0.46	0.50	0.60	0.54
6	25%	0.40	0.50	0.44	0.70	0.89	0.78	0.67	0.33	0.44	0.40	0.60	0.48	**1.00**	**1.00**	**1.00**
(504)	50%	0.55	0.45	0.50	0.63	0.55	0.58	0.67	0.63	0.64	0.66	0.75	0.70	**0.83**	**0.78**	**0.80**
7	25%	0.55	0.67	0.59	0.80	0.67	0.73	**0.83**	**1.00**	**0.91**	0.50	0.43	0.46	0.50	0.43	0.46
(694)	50%	0.46	0.71	0.56	0.40	0.57	0.47	0.43	0.71	0.54	**0.62**	**0.57**	**0.59**	0.30	0.43	0.35
8	25%	0.33	0.60	0.43	0.50	0.50	0.50	**0.75**	**0.60**	**0.67**	0.55	0.55	0.55	0.20	0.33	0.25
(681)	50%	0.30	0.36	0.33	0.36	0.46	0.40	**0.80**	**0.74**	**0.77**	0.40	0.66	0.50	0.53	0.73	0.62
9	25%	**0.67**	**1.00**	**0.80**	0.25	0.50	0.33	0.20	0.33	0.25	0.50	0.50	0.50	0.40	0.67	0.50
(608)	50%	0.40	0.46	0.43	0.44	0.61	0.52	0.50	0.69	0.58	**0.80**	**0.75**	**0.77**	0.60	0.69	0.64
10	25%	0.33	0.33	0.33	0.67	0.67	0.67	**1.00**	**0.75**	**0.86**	0.67	0.67	0.67	0.67	0.50	0.57
(388)	50%	0.33	0.33	0.33	0.55	0.55	0.55	**0.89**	**0.80**	**0.84**	0.67	0.50	0.57	0.55	0.55	0.55
Average	25%	0.41	0.48	0.43	0.56	0.62	0.57	**0.70**	**0.65**	**0.66**	0.48	0.56	0.51	0.44	0.50	0.54
	50%	0.43	0.47	0.44	0.52	0.58	0.55	**0.65**	**0.69**	**0.66**	0.54	0.57	0.54	0.46	0.52	0.48

Table 1 Comparison of the 25% and 50% summaries of 10 randomly selected text files of DUC 2002, outside the training texts.

Word, Copernic and the Narrow Window approach only provided the best results only in two, one, and one instances, respectively. For both 25% and 50% summaries, the average F-values for the Sentence Context approach was 0.66. The next highest average F-value for 25% summaries was 0.57 for the Extended Approach, compared to 0.56 for the 50% summaries.

The results of these limited experiments clearly indicate that the summaries created by the proposed scheme (in particular for the Sentence Context and Extended Window approach) are very close to the human generated summaries, especially when compared to existing summarizers at both 25% and 50% level. These results are certainly very promising. However, it is too early to predict how the neural network along with Random Indexing based scheme will work in general.

5. Conclusion

In this work, we propose a scheme for text summarization using Random Indexing and neural networks. The approach exploits the similarity in the meaning of the words by mapping them onto the word space and removing less important sentences by sieving them through a neural network already trained on a set of summarized text.

The problem of high dimensionality of the semantic space has been tackled by employing Random Indexing, which is less costly in computation and memory consumption than other dimensionality reduction approaches. The selection of features as well as the selection of summary sentences by the human reader from the training paragraphs plays an important role in the performance of the network. The network is trained according to the style of the human reader, since it recognizes which sentences in a paragraph the human reader emphasizes. This is an advantage that the proposed approach provides; allowing an individual reader to train the neural network according to one's own style. Furthermore, the selected features can be modified to reflect the reader's needs and requirements. In future research, we plan to create a more complex neural network structure, involving better activation functions, to smooth out some abruptness that we encountered in the current schemes. Moreover, in our present evaluation we have used measures like precision, recall and F, which are used primarily in the context of information retrieval. In the future, we intend to use more summarization-specific techniques to measure the efficacy of our scheme.

In order to develop the proposed technique into an efficient summarization tool, we need to address a number of uncertainties, including the the dimension of the index vectors and the size of the neural network. We aim to find optimum values for these parameters for the proposed model.

In the present scheme, we have used three different approaches: Narrow Window, Extended Window and Sentence Context. We have noticed that the on the average the Sentence Context approach produces the best result. However, other appproaches have produced superior results in several test cases. More experimentation is needed with the Sentence Context approach in order to elevate its performance level. Alternatively, we may have to suitably combine the three proposed approaches in order to produce good results uniformly. We are

currently working towards these goals.

Notes

1. See Luhn, 1958; Edmunson, 1969; Mani and Bloedorn, 1999; Kaikah, 2004.
2. www.copernic.com/en/products/summarizer/
3. www.microsoft.com/education/autosummarize.mspx/
4. See Rojas, 1996 and Bishop, 2005 for details of Backpropagation algorithm.
5. http://www.wardsystems.com/manuals/neuroshell2

References

1. Bishop, C. M. (2005). Neural Networks for Pattern Recog¬nition. Oxford Press.
2. Chatterjee, N. and Mohan, S. (2007). Extraction-based single-document summarization using random indexing. In ICTAI (2), pages 448–455.
3. Edmundson, H. P. (1969). New methods in automatic extracting. J. ACM, 16(2):264–285.
4. Higgins, D., Burstein, J., Marcu, D., and Gentile, C. (2004). Evaluating multiple aspects of coherence in student essays. In HLT-NAACL, pages 185–192.
5. Kaikhah, K. (2004). Text summarization using neural networks. WSEAS Transactions on Systems3, 3:960–963.
Kanerva, P. (1988). Sparse distributed memory. Cambridge: MIT Press.
6. Karlgren, J. and Sahlgren, M. (2001). From words to understanding: Foundations of real-world intelligence. CSLI Publications.
7. Kupiec, J., Pedersen, J. O., and Chen, F. (1995). A trainable document summarizer. In SIGIR, pages 68–73.
8. Luhn, H. (1958). The automatic creation of literature abstracts. IBM Journal of Research and Development.
Mani, I. and Bloedorn, E. (1999). Summarizing similarities and differences among related documents. Inf. Retr., 1(1-2):35–67.
9. Rojas, R. (1996). Neural Networks: A Systematic Introduction. Springer-Verlag, Berlin.
10. Sahlgren, M. (2005). An introduction to random indexing. In Proceedings of the Methods and Applications of Semantic Idexing Workshop at the 7th International Conference on Terminology and Knowedge Engineering.
11. Sahlgren, M. (2006). The Word-Space Model: Us-ing distributional analysis to represent syntagmatic and paradigmatic relations between words in high-dimensional vector spaces. Ph.D. dissertation, De¬partment of Linguistics, Stockholm University.
12. Yates, R. and Neto, B. (1999). Modern Information Re¬trieval. Pearson Education.

Avikant Bhardwaj is a senior undergraduate at Indian Institute of Technology Delhi (India), majoring in Mathematics and Computing. His research interests include Linear and Non-linear Programming, Machine Learning, Financial Engineering and Natural Language Processing.