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The editors of this journal wish to thank the Office of Vice President for Research and the Office of Student Affairs, as well as the undergraduate research coordinators for each college for their generous support and guidance.

They also thank the University Co-Op for their generous support.

They offer their appreciation as well to Ms. Veronica Cantu, Ms. Becky Carreon, Dr. Soncia Reagins-Lilly, Dr. Rebecca Wilcox, the UT Office of Undergraduate Research, and the Senate of College Councils for helping make the UT Austin Undergraduate Research Journal possible.

FROM THE EDITOR

This year's Editorial Board is proud to present the 12th edition of the University of Texas at Austin's Undergraduate Research Journal. With generous support from the Office of the Vice President for Research, the Office of Student Affairs, and the University Co-Op, we've produced another Journal that truly reflects the breadth and depth of undergraduate research being conducted at UT. This year we received submissions from an impressive variety of disciplines, articles that showcase the curiosity and passion of their authors—it was extremely difficult to narrow down the pieces on energy, robotics, Graham Greene, regeneration by fragmentation, macroalgae, and upper-class identity in Texas that we present in this edition.

This year, the URJ hosted several exciting new events to promote the tradition of undergraduate research. In the fall, we hosted a business research panel with special guest UBS. During Research Week, an annual event hosted by the Office of Undergraduate Research, we co-hosted a writing workshop with the Undergraduate Writing Center in order to better equip students with the skills necessary for writing specifically for publication in scholarly journals. Prior to the Journal's submission deadline, we also began a tradition of annual information sessions to familiarize potential authors with the URJ's mission and selection criteria.

I would also like to personally thank everyone who made this year's edition of the journal possible. The Senate of College Councils, the Office of Undergraduate Research, our aforementioned sponsors, and of course the members of the editorial board each provided the Journal with invaluable support. We're proud to say that this year, the journal unquestionably fulfllled its mission of promoting undergraduate research.

Sincerely,

Emily Gruener

Contents

UNDERGRADUATE RESEARCH JOURNAL | 2014

Diversity and Taxonomic Richness of Macroalgae among Cenotes of the Eastern Yucatan Peninsula

The University of Texas at Austin

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Madison L. Becker, Sylvia F. Garza and Christopher Wood

Abstract

The karst topography of the Yucatan Peninsula creates a unique hydrologic system of underground waterways that allow for the transport of water across the peninsula to the sea. Collapsed sections of this system create open-air sinkholes filled with fresh groundwater known as cenotes. In cenotes, macroalgae are important primary producers that form the base of complex food webs. The purpose of this study was to explore macroalgal communities in cenotes and determine the hydrographic parameter(s) responsible for macroalgae diversity and taxonomic richness. In order to assess this, we sampled 9 cenotes on the Yucatan

Peninsula near Akumal, Quintana Roo, Mexico; Akumal Bay in the Caribbean Sea was used as a marine reference site. Samples of macroalgae were collected at each site and identified to genus level, and species level when possible. Hydrographic measurements were taken using a YSI Data Sonde. There was a significant correlation between number of taxa (richness) and salinity from each site ($R^2 = 0.79$, $p = 0.0071 < 0.01$). The sites had an average salinity of 13.38 ± 5.2 (7) ppt (x ± SE (n)) with the largest salinity variation in Yal Kú (24.75 ± 3.3 (6) ppt). The three most diverse sites: Akumal Bay (33 taxa), Yal Kú (39 taxa) and Cenote Manatee (19 taxa) had direct connections to the sea. Diversity generally decreased as distance from the sea increased in sites: Xcacel Xcacelito (7 taxa), Laguna Lagartos (12 taxa), Cenote Akumak (12 taxa) and Cenote Dos Ojos (9 taxa). The furthest three sites: Cenote Balam (3 taxa), Laguna de Cocodrilo (5 taxa) and Laguna de Uxuxubi (4 taxa) were the least diverse. These results suggest that macroalgae diversity and taxonomic richness in cenotes are strongly influenced by salinity, making this study the first to introduce salinity as a mechanism driving macroalgal communities in these systems.

Introduction

The Yucatan Peninsula is home to one of the largest and most unique aquatic systems on Earth (Gondwe et al. 2010). This important system is characterized by a series of karstic aquifers formed from the dissolution of limestone bedrock by acidic rainwater. The result is a porous, conglomerate substrate riddled with caverns and underground waterways (Worthington 2009). The porous nature of this bedrock allows for rapid soil absorption of precipitation and facilitates groundwater flow (Mutchler et al. 2010). These factors combined with a high rate of evapotranspiration make surface water accumulation difficult. As a result, lakes and rivers do not readily form on the peninsula (Alcocer et al. 1997). Instead, the primary sources of freshwater are collapsed sections of the cavern system, known as cenotes.

Cenotes are generally accepted as any body of water confined in a limestone cavity including the classic sinkhole, shallow lakes or "lagunas", and many lagoons (Scholz et al. 1995, Alcocer et al. 1997). Cenotes exist across the interior of the peninsula extending all the way to the shoreline. The surrounding environment of a cenote can have a strong influence on its hydrographic characteristics; factors such as surrounding vegetation, amount of available sunlight, and rate of water flow through each cenote can change drastically by location (Alcocer et al. 1997). Underground waterways, or conduits, allow for the landward movement of seawater from the coast, with some extending as far as 10 km inland (Beddows et al. 2007). Thus, distance from the shoreline can also have a strong impact on the hydrographic parameters of a cenote. Cenotes further from the coast are generally freshwater, while those closer to the coast are often subject to stratification as a result of the mixing of fresh groundwater and salty seawater (Schmitter-Soto et al. 2002). Since cenotes are the most common open-air sources of freshwater on the peninsula, they serve as extremely important resources for surrounding life and are host to a range of small yet dynamic aquatic ecosystems.

At the base of these ecosystems are the photosynthetic primary producers called algae. Of these algae, macroalgae are particularly important in providing cenotes with oxygen and organic material to support complex food webs (Littler et al. 1989, Lantz 2013). Three main types of macroalgae exist on the Yucatan Peninsula: Chlorophyta (green), Rhodophyta (red), and Phaeophyta (brown). Green algae are the most abundant in fresh waters, but can also be commonly found in the surrounding Caribbean Sea. Red algae boast the most diverse and numerous species in these tropical waters, having been found in water ranging from shallow shores to great depths. Brown algae are by far the least abundant on the Yucatan Peninsula; however, genera like *Sargassum* and *Turbinaria* have been known to dominate select areas (Littler et al. 1989).

Akumal is a region located on the eastern part of the Yucatan Peninsula in the state of Qunitana Roo, Mexico. It lies at 20°28'37.16"N and 87°16'42.18"W between the cities of Tulum and Cancun. With population and urbanization on the rise, an understanding of the unique hydrologic system of the area has become increasingly important (Alcocer et al. 1997). Due to the porous nature of karst topography, cenotes are uniquely susceptible to anthropogenic effects such as chemical runoff and sewage (Metcalfe et al. 2010). Increasing urbanization and tourism across the Yucatan Peninsula could stand to exacerbate these effects, potentially degrading the vital resources and biological value of these systems. Although baseline information is crucial for the maintenance of both the human population and the health of the ecosystem, the biology of cenotes has not been thoroughly investigated (Mejía-Ortíz et al. 2007).

The primary objective of this study was to compare macroalgal diversity and taxonomic richness of nine cenotes near Akumal by collecting samples and identifying algae to genus, and species level if possible. The secondary objective was to measure various hydrographic parameters in cenotes and determine any possible correlations between these parameters and the residing algal communities. We predicted that there would be greater diversity of macroalgae in cenotes closer to the coast because these cenotes are subject to a broader range of niches as a result of stronger marine influence. In addition, we expected diversity and richness to differ between cenotes closer to the coast and those further inland as a result of varying hydrographic parameters.

Methods

2.1 Site description

This study was conducted from May 17th to May 29th, 2013. We sampled 10 total sites: 9 cenotes and 1 bay as a reference site (note: names of sites do not imply a geologic description, except for Akumal Bay). Sampled sites ranged from highly marine-influenced (direct connection to the sea) to very low marine-influenced (>10 km away from the coast line) (Table 1, Figure 1). Marine-influenced sites included Yal Kú, Cenote Manatee, Laguna Lagartos, and Xcacel Xcacelito. Sites of low-marine influence included Cenote Akumak, Cenote Dos Ojos, Cenote Balam, Laguna de Cocodrilo, and Laguna de Uxuxubi. The reference site, Akumal Bay, is entirely marine and therefore assumed to have the greatest macroalgal diversity based on the factors focused on this paper. The bay is enclosed on its outer edge by the Mesoamerican Barrier Reef. This coral reef protects the bay's extensive seagrass beds (containing: *Halodule wrightii*, *Thalassia testudinum* and *Syringodium filiforme*), which support a large sea turtle population. Commercial resorts, hotels, dive shops and restaurants surround the shoreline side of the bay.

Table 1. **Sites and general descriptions.** Sampled from May 17 to 29, 2013. One reference site and nine cenotes were sampled. Appendix B shows pictures and descriptions of each site for reference.

Study Sites	Location	Day Sampled	Distance from the ocean (m)	Depth (m)	Habitat description
Akumal Bay	20°28'37. 16"N 87°16'42. 18"W	May 19 and 22	NA	NA	Foreshore consisted primarily of sandy bottom, continued by seagrass beds and finally coral heads. Few predators, largely dominated by herbivorous fish (e.g. parrotfish, damselfish, chubs).
Yal Kú	20°24'42. 14"N 87°18'14. 96"W	May 27	Inner section: 369. 41 Outer section: Connected to ocean	NA	Open cenote, largely dominated by small herbivorous fish. Inner section: rocky substrate, freshwater, algae-dominated. Outer section: sandy bottom, marine, coral-dominated.
Cenote Manatee	20°16'0. 33"N 87°23'30. 79"W	May 17 and 29	Inner section: 203. 91 Outer section: 64. 96	5	Open cenote, surrounded by red mangroves. Mostly rocky substrate, algae-dominated. Largely dominated by small herbivores fish and a few carnivores, such as tarpon.
Xcacel Xcacelito	20°20'16. 25"N 87°20'57. 10"W	May 24	129.77	3.5	Open cenote, surrounded by red mangroves. Rocky bottom, algae-dominated. Populated by small herbivorous fish and visited by freshwater turtles.
*Laguna Lagartos	20°24'3. 98"N 87°18'43. 28"W	May 19 and 21	311. 78	3.14 4.734 1.83 2.8	Open shallow system. Composed of one main cenote and three small ones hidden in the jungle; all 4 connected through underwater system. Rocky bottom and surface covered with algae. Non-potable water.

Cenote Akumak	20°23'53. 29"N 87°20'25. 70"W	May 18	2, 281. 85	2.11	Cenote partially covered by rocks. Bottom of opened part of cenote covered with algae. Rocky substrate and clear water on covered (cave-like) part of cenote.
*Cenote Dos Ojos	20°19'28. 82"N 87°23'28. 74"W	May 24	3, 876. 61	4.3 1.15 3.1	Cenote completely covered by rocks. Composed of three small cenotes connected by underwater cavern system. Mostly sandy bottom. Water populated by small herbivorous fish and snails; cavern roofs populated by bats, birds and bees.
Cenote Balam	20°26'53. 20"N 87°23'26. 00"W	May 25	9, 774. 91	1.59	Cenote partially covered. Cavern roof populated by bats and bees. Murky water with thick mats of algae along the surface.
Laguna de Cocodrilo	20°27'28. 79"N 87°23'31. 07"W	May 26	10, 423. 61	4.8	Cenote populated by crocodiles. Turbid water surrounded by red mangroves.
Laguna de Uxuxubi	20°27'31. 12"N 87°23'40. 67"W	May 26	10, 751. 80	2.6	Cenote turned into a large quarry for the harvest of stone. Disturbed sediment that clouded water column. Possibly inhabited by crocodiles.

*Coordinates from Laguna Lagartos corresponds to the location of the main (largest) cenote and the distance is the average from all four cenotes. Distance from the ocean and coordinates for Cenote Dos Ojos correspond to the main (largest) cenote.

2.2 General methodology

Temperature (oC), salinity (ppt), pH and dissolved oxygen (DO) (mg/L) were collected at each location (with the exception of Yal Kú) using a YSI datasonde. Macroalgae were collected randomly and placed in reusable plastic bags (note: for the purpose of this study, macroalgae were characterized as any algae that can be seen without the aid of a microscope). In lab, samples were examined with compound and dissecting microscopes and identified to genus, and species level (if possible), using Caribbean and freshwater algae identification keys (i.e. Littler et al. 1989, and Littler and Littler 2000). Linear regressions were used to determine any correlations between number of taxa and hydrographic parameters.

The method of collection varied depending on the accessibility of each site. As a safety precaution, minimal samples were collected along the edges of Cenote Balam, Laguna de Cocodrilo and Laguna de Uxuxubi because crocodiles inhabited these systems. When possible, we collected algae attached to rocks, floating plant matter and reached submerged algae by scraping the bottom. Due to these sampling limitations, we did not include these sites while comparing hydrographic data variation between sites and in the statistical analyses between these data and taxonomic richness. We did, however, include them in the analysis of

Figure 1. **Site Map.** Yucatan Peninsula (left) and location of ten studied sites (right).

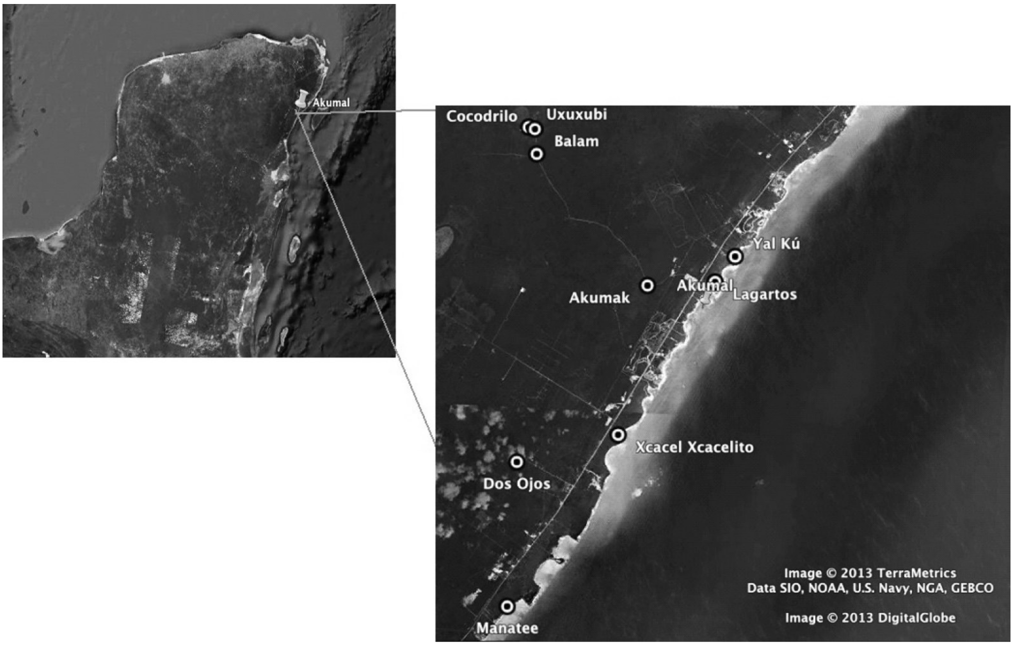
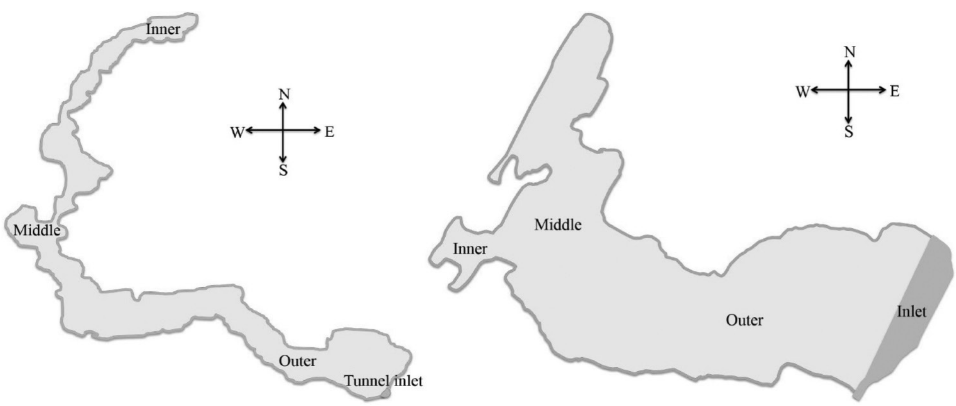


Figure 2. **Top view sketch of Cenote Manatee (left) and Yal Kú (right).** Inner, middle and outer sections sampled by collecting algae in plastic bags. Cenote Manatee is connected to the ocean through a tunnel below water and Yal Kú contains an open inlet. These connections to the ocean allow for fresh and seawater exchange.



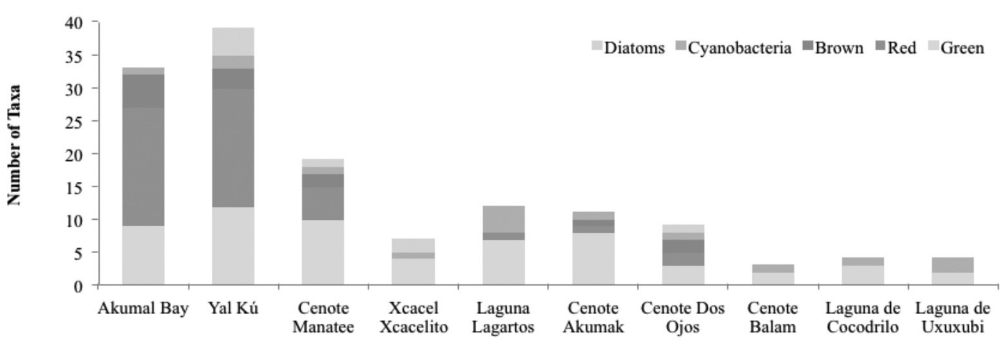
macroalgal diversity since it is a representation of the macroalgal communities we observed at each site. In Akumal Bay, Laguna Lagartos, Xcacel Xcacelito, Cenote Akumak and Cenote Dos Ojos we sampled randomly from any area were we saw algal growth while snorkeling.

Salinity was assumed to vary within Yal Kú and Cenote Manatee, due to their extended shapes and small area of contact with the ocean (Figure 2). For this reason, we divided these sites into inner, middle and outer sections and conducted hydrographic measurements and macroalgae samplings accordingly. Cenote Manatee was sampled twice to make sure any difference in diversity between sections was detected. At Yal Kú, we collected top (anything not attached to sandy or rocky substrates) and bottom samples from each section (Figure 2). We were not able to transport a sonde to Yal Kú. Therefore, we collected surface and bottom waters from each section in small vials and measured salinity in lab using a refractometer. The rest of the hydrographic parameters (temp., pH and DO) could not be assessed in this site.

Results

In general, macroalgal communities differed between sites further inland and sites closer to the sea (Figure 3). Cenote Balam, Laguna de Cocodrilo and Laguna de Uxuxubi were the furthest away from the sea and consisted of green algae and cyanobacteria. Yal Kú and Cenote Manatee, located closer to the coast, had the highest red and green algae diversity. Akumal Bay had the highest brown algae diversity, followed by Yal Kú. Xcacel Xcacelito, Laguna Lagartos and Cenote Akumak were in between the two extremes (furthest inland and closer to coast) and consisted of mostly green algae, but had some red, brown, diatoms and cyanobacteria as well.

Figure 3. **Macroalgae diversity.** Nine cenotes and one reference site (Akumal Bay). Sites on the x-axis are in order of increasing distance from the sea. Data collected from May 17 to 29, 2013.



The sites had an average temperature of 26.11 ± 0.4 (6) °C (x ± SE (n)) (Table 2) with the largest variation within Cenote Manatee with 25.76 ± 0.4 (10) °C (excluding the sites Balam, Cocodrilo and Uxuxubi). There was no significant relation between number of taxa and temperature of each site (R^2 = 0.75, p = 0.0262 > 0.01). The average pH of the study sites was of 6.92 ± 0.2 (6) with the largest variation within Cenote Akumak with 6.84 ± 0.1 (3) (Table 2). There was no significant relation between number of taxa and pH (R^2 = 0.79, p = 0.0173). The sites had an average dissolved oxygen of 4.16 ± 1.3 (6) mg/L with the largest variation within Cenote Akumak with 3.71 ± 1.4 (3) mg/L (Table 2). There was no significant correlation between number of taxa and DO of each site (R^2 = 0.83, p = 0.0112).

Salinity and number of taxa from each site were significantly correlated (R^2 = 0.79, p = 0.0071 < 0.01), where number of taxa increased linearly as salinity increased (Figure 4). The sites had an average salinity of 13.38 ± 5.2 (7) ppt with the largest salinity variation within Yal Kú with 24.75 ± 3.3 (6) ppt (Table 2). Xcacel Xcacelito had the lowest number of taxa of 7 at low salinity of 4.34 ppt (Appendix A, Table 2). Yal Kú had the highest number of taxa at 39 and the second highest salinity of 24.75 ppt (Appendix A, Table 2). Akumal Bay, had the second highest number of taxa at 33 and the highest salinity at 38.96 ppt (Appendix A, Table 2).

Figure 4. **Macroalgae taxonomic richness** (number of taxa) with increasing salinity. Six cenotes and one reference site. Data collected from May 17 to 29, 2013. 79% of the variation in number of taxa can be explained by salinity.

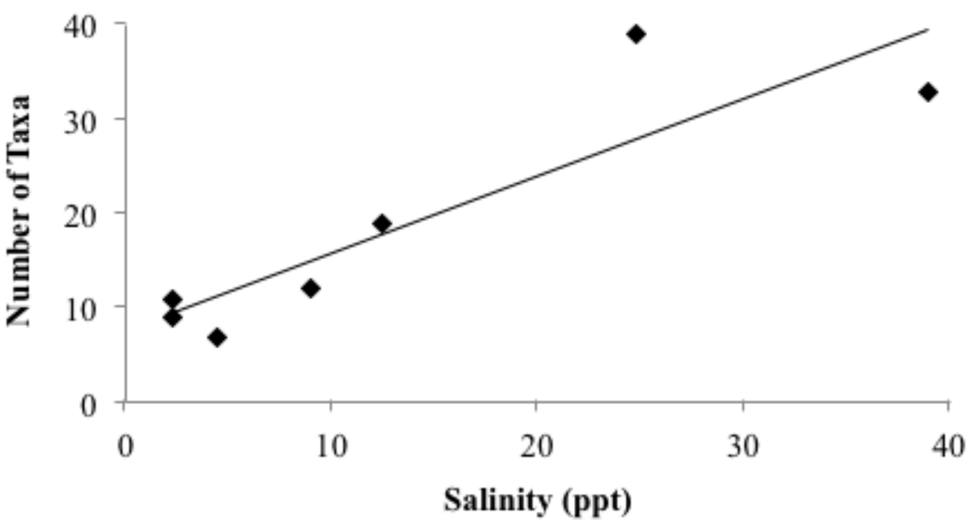
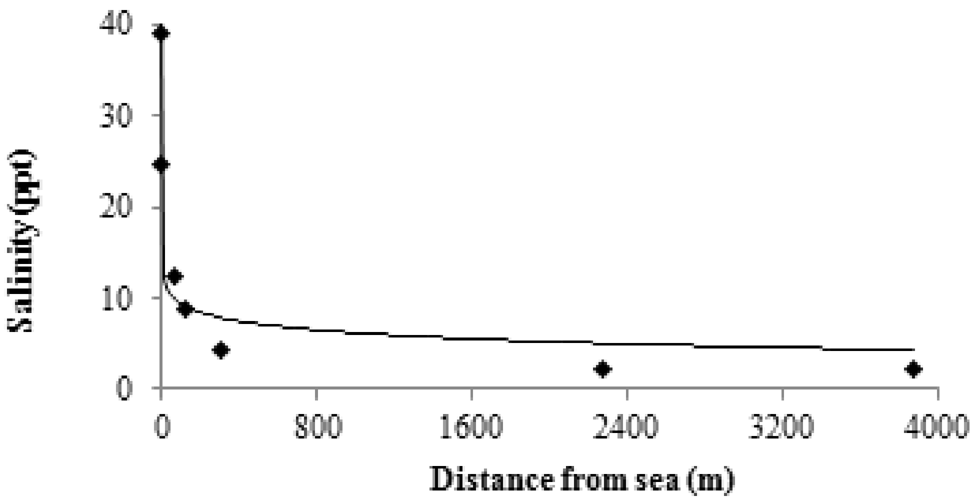


Figure 5. | **Figure 5. Salinity with increasing distance from the sea.** Six cenotes and one reference site**.** Data collected from May 17 to 29, 2013. 89% of the variation in salinity can be explained by distance from the sea.



There was no correlation between number of taxa and distance from the sea ($R^2 = 0.50$, $p = 0.0732 > 0.01$). However, salinity and distance from the sea were significantly correlated ($R^2 = 0.89$, $p = 0.0011$), where salinity decreased as distance from the sea increased (Figure 5). Yal Kú is directly connected to the sea and is therefore closest with the highest salinity of 24.75 ppt (Figure 4, Table 2). Cenote Dos Ojos and Cenote Akumak are the furthest from the sea at 3,876. 61 m and 2,281. 85 m with the lowest salinities of 2.18 ppt and 2.19 ppt, respectively (Table 1, Table 2).

Table 2. Hydrographic parameters. Sampled from May 17 to 29, 2013. Used YSI datasonde for all sites, except Yal Kú (water samples were collected and measured salinity with refractometer). Values are x ± SE (n).

Study Sites	Temperature (°C)	Salinity (ppt)	pH	DO (mg/L)
Akumal Bay	28 .00 (1)	38.96 (1)	8.14 (1)	10.69 (1)
Yal Kú	NA	24.75 ± 3.3 (6)	NA	NA
Cenote Manatee	25.76 ± 0.4 (10)	12.37 ± 0.2 (10)	6.61 ± 0 (10)	2.71 ± 0 (10)
Xcacel Xcacelito	25.51 ± 0 (2)	4.34 ± 0 (2)	6.56 ± 0 (2)	2.02 ± 0 (2)

*Laguna Lagartos	26.63 ± 0.2 (12)	8.91 ± 0 (12)	6.69 ± 0 (12)	3.58 ± 0.5 (12)
Cenote Akumak	25.51 ± 0.2 (3)	2.19 ± 0 (3)	6.84 ± 0.1 (3)	3.71 ± 1.4 (3)
*Cenote Dos Ojos	25.22 ± 0 (7)	2.18 ± 0 (7)	6.47 ± 0 (7)	2.24 ± 0 (7)
Cenote Balam	25.43 ± 0.3 (2)	1.08 ± 0 (2)	6.40 ± 0 (2)	2.55 ± 0.9 (2)
Laguna de Cocodrilo	27.34 ± 2.1 (3)	1.11 ± 0 (3)	7.14 ± 0.4 (3)	4.32 ± 1.7 (3)
Laguna de Uxuxubi	27.36 ± 1.0 (5)	1.11 ± 0 (5)	7.44 ± 0.1 (5)	5.68 ± 1.0 (5)

*Averaged hydrographic parameters of individual systems for Laguna Lagartos and Cenote Dos Ojos.

Discussion

As we predicted, there was a general increase in macroalgal diversity within sites as the distance from the sea decreased (Figure 3), but there was no correlation between distance and taxonomic richness (number of taxa). The data showed that macroalgal richness tended to change more as a function of salinity (Figure 4). Brown and red algae were present in Akumal Bay and sites of higher salinity, but absent in the three freshest sites: Cenote Balam, Laguna de Cocodrilo and Laguna de Uxuxubi. Brown and red algae thrive in more saline waters and most cannot tolerate freshwater, potentially indicating a wider variety of niches to be filled in areas of increasing salinity (Kirst 1989). Not only did the marine reference site and higher salinity sites had red, brown, and green algae, but they also contained a substantially greater number of taxa in total, as well as within each category (Figure 3 and 4). There were genera of both green algae and cyanobacteria found in all of the sampled sites. These groups tend to have a wider range of tolerance, and therefore the opportunity to occupy a wider variety of biological niches (Kirst 1989, Schubert et al. 2011).

This relationship is particularly evident when comparing Laguna Lagartos and Xcacel Xcacelito. Laguna Lagartos is more than twice the distance from the sea than Xcacel Xcacelito, yet there were 12 taxa identified in Laguna Lagartos and only 7 taxa identified in Xcacel Xcacelito. Looking at salinity however, we see that an increase from 4.34 ppt in Xcacel Xcacelito to 8.91 ppt in Laguna Lagartos almost doubles the number of taxa present. Since algal growth is significantly affected by the amount of freshwater input (Martins et al. 2001), it is suggested that diversity is in large part driven by salinity, and that salinity is merely a side effect of coastal proximity. It has also been shown, however, that nutrient levels in these systems are strongly correlated with freshwater input (Mutchler et al. 2007). Massive growth of green algae like Cladophora spp. (a green found in all but two of the sites) indicates a high level of terrestrial input, making it likely that these nutrient sources also strongly contribute to the composition of algal communities (Mutchler et al. 2010, McCormick and Cairns 1994).

Laguna de Uxuxubi, Laguna de Cocodrilo and Cenote Balam were the furthest cenotes from the sea and were located within 1 km of one another. Though they appeared wildly different at first glance, they demonstrated very similar algal composition. Laguna de Uxuxubi was shallow, open, and barren with mostly clear, blue water. Laguna de Cocodrilo was deep, surrounded by red mangroves, with turbid water full of dissolved organic matter, which can limit light penetration and therefore primary productivity of algae (Jones 1992, Carpenter et al. 1998). Cenote Balam was set within a cliff-face that diminished sunlight availability, and the water seemed fetid and stagnant. However, because of their close proximity, they have groundwater sources in common (Hynes 1983). Therefore it is likely that the composition of this water had little opportunity to change during transport between sites. Due to the quality of water in Cenote Balam, and the presence of crocodiles in Laguna de Uxuxubi and Laguna de Cocodrilo, we could not get in the water and were forced to sample only along the edges. As a result, similarities in algal diversity may also be attributed to the fact that our sampling area was minimal. Although the sampling methods were not as thorough as in other sites, the data collected here is still valuable in expanding baseline biology. The taxa found in these sites included Cladophora spp., Spirogyra sp. and several cyanobacteria. Each of these groups can be found in a wide range of water conditions and geographic locations. This indicates that these groups are simply the most tolerant of varying and unfavorable conditions, and could also be a reason for the similarity between these sites (Guiry et al. 1996).

Cenote Manatee and Yal Kú are particularly unique because of their direct connections to the sea (Figure 2). Cenote Manatee is connected through an underground conduit, which allows for water exchange, while Yal Kú contains an open inlet to the sea. Cenote Manatee did not show significant changes in salinity from the inner, middle, and outer regions sampled (Table 2). There was also no significant difference in the algal communities between these sections, with the exception of Halimeda spp., which was found only near the outer region. Furthermore, there was no blur effect in this system caused by intense stratification of waters suggesting that the system was well mixed; this may explain why there was no major variation of algae within it.

Contrarily, Yal Kú showed great variation in salinity, taxonomic richness and diversity between sections. At the innermost region, which is also the freshwater source, the surface salinity was 17.5 ppt and bottom salinity was 15 ppt. It was composed of primarily green algae and cyanobacteria with a few marine genera such as Halimeda spp. (green) and Ceramium sp. (red). The middle section was characterized by a mangrove island surrounded by blurry, turbid water with distinctly brown coloration on the surface, and clear blue water sitting underneath. The number of taxa found here decreased from that of the inner region, but the composition was more marine. Surface salinity in the outermost region was 30 ppt and bottom was 33 ppt; water was clear and algae taxa were almost entirely marine. Yal Kú had greater macroalgal diversity and number of taxa than Akumal Bay, even though the control group had the highest salinity. This is due to freshwater, brackish and marine niches Yal Kú provides for different macroalgae communities. The pattern found at Yal Kú further supports the idea of salinity as an important driver of diversity in algal communities.

Though dissolved oxygen (DO) and number of taxa show a possible, but insignificant correlation, these factors are only indirectly related. Each site is fed by groundwater, and due to low primary productivity in groundwater DO levels are also very low (Malard and Hervant 1999, Baker et al. 2000). Primary producers in the water column and on the surface (e.g. macroalgae, phytoplankton) directly affect the amount of dissolved oxygen (Yoshikawa et al. 2007). This is evident when comparing Xcacel Xcacelito and Akumal Bay. Xcacel Xcacelito, which had the lowest DO (2.02 mg/L) was relatively fresh, suggesting high groundwater influence unlike the marine water of Akumal Bay, which had the highest DO (10.69 mg/L). It is also important to note that DO measurements were taken only once at each location. DO is regularly high during the day due to photosynthetic activity, and low at night due to lack of sunlight and microbial activities (Savidge 1988). Thus, constant monitoring would be required to account for the temporal and spatial changes of DO within each site. With this in mind, we believe that the correlation can be explained by a combination of factors which directly affect DO and number of taxa individually. This creates what looks like a direct relationship between two variables that are actually independent of one another.

Even though pH varied between cenotes, there was no significant relationship between pH and number of taxa because the taxonomic richness and diversity of macroalgae do not depend on this factor (Littler et al. 1989, Littler and Littler 2000). Due to the focus of this research, we did not measure acidity or carbon dioxide in the water, though we believe that these water parameters are what mainly influenced the pH variation between sites (Hall-Spencer et al. 2008). Similarly, there was no correlation between temperature and number of taxa, but this is likely because temperature did not widely vary.

Conclusion

Cenotes are important hydrologic features of the Yucatan Peninsula. They are crucial for the transport of water to the sea, they provide freshwater for consumption and recreation, and they create unique biological systems. Primary producers like macroalgae are a critical component at the foundation of these systems providing oxygen, food and habitats for fish and invertebrate communities. This study is the first to introduce salinity as a mechanism driving diversity of macroalgae in these systems. It contributes to existing algal taxonomy and hydrographic measurements in a number of cenotes previously studied, while also providing new information at several unstudied sites. Although we have begun to form an important basline of information, each of these systems is truly dynamic and will require further and more extensive research to substantially define their biology and predict potential changes caused by increasing anthropogenic activity.

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References

Alcocer, J., A. Lugo, L.E. Marín and E. Escobar. 1997. Hydrochemistry of waters from five cenotes and evaluation of their suitability for drinking-water supplies, northeastern Yucatan, Mexico. *Hydrogeology Journal*, 6: 293-301.

Baker, M.A., H. M. Valett and C.N. Dahm. 2000. Organic Carbon Supply and Metabolism in a Shallow Groundwater Ecosystem. *Ecology*, 81: 3133-3148.

Beddows, P.A., P.L. Smart, F.F. Whitaker and S.L. Smith. 2007. Decoupled fresh-saline groundwater circulation of coastal carbonate aquifer: spatial patterns of temperature and specific electrical conductivity. *Journal of Hydrology*, 346: 18-32.

Carpenter, S.R., N.F. Caraco, D.L. Correll, R.W. Howarth, A.N. Sharpley and V.H.Smith. 1998. Nonpoint pollution of surface waters with phosphorus and nitrogen. *Ecological Applications,* 8: 559-568

Gondwe, B.R.N., S. Lerer, S. Stisen, L. Marín, M. Rebolledo-Vieyra, G. Merediz-Alonso and P. Bauer-Gottwein. 2010. Hydrogeology of the south-eastern Yucatan Peninsula: New insights from water level measurements, geochemistry, geophysics and remote sensing. *Journal of Hydrology*, 389: 1-17.

Guiry, M., W. Guiry, S. Valenzuela Miranda, A. Langangen and D. Garbary. 1996. AlgaeBase. Accessed May 2013 <www.algaebase.org>.

Hall-Spencer, J.M., R. Rodolfo-Metalpa, S. Martin, E. Ransome, M. Fine, S.M. Turner, S.J. Rowley, D. Tedesco and M.C. Buia. 2008. Volcanic carbon dioxide vents show ecosystem effects of ocean acidification. *Nature*, 454: 96-99.

Hynes, H.B.N. 1983. Groundwater and stream ecology. *Hydrobiologia*, 100: 93-99.

Jones, H.G. 1992. Plants and Microclimate 2nd Ed. Cambridge University Press, Cambridge.

Kirst, G.O. 1989. Salinity Tolerance of Eukaryotic Marine Algae. *Annual Review of Plant Physiology and Plant Molecular Biology,* 41: 21-53.

Lantz, E. 2013. Biological and Hydrological Characteristics of Coastal Cenote Habitats Surrounding Akumal, Quintana Roo, Mexico. *Undergraduate Research Journal*, University of Texas at Austin, 12: 81-103

Littler, D.S., M.M Littler, K.E. Bucher and J.N. Norris (Eds.) 1989. Marine Plants of the Caribbean. A Field Guide from Florida to Brazil. Washington D.C.: Smithsonian.

Littler, D.S. and M.M Littler. (Eds.) 2000. Caribbean Reef Plants. Washington D.C.: Offshore Graphics, Inc.

Malard, F. and F. Hervant. 1999. Oxygen supply and the adaptations of animals in groundwater. *Freshwater Biology*, 41: 1-30.

Martins, I., M.A. Pardal, A.I. Lillebo, M.R. Flindt and J.C. Marques. 2001.

Hydrodynamics as a Major Factor Controlling the Occurrence of Green Macroalgal Blooms in a Eutrophic Estuary: A Case Study on the Influence of Precipitation and River Management. *Estuarine, Coastal and Shelf Science*, 52: 165-177.

McCormick, P.V. and J. Cairns Jr. 1994. Algae as indicators of environmental change. *Journal of Applied Phycology,* 6: 509-526.

Mejía-Ortíz, L.M., G. Yáñez, M. López-Mejía and E. Zarza-González. 2007. Cenotes (anchialine caves) on Cozumel Island, Quintana Roo, Mexico. *Journal of Cave and Karst Studies*, 69: 250-255.

Metcalfe, C. D., P.A. Beddows, G.G. Bouchot, T.L. Metcalfe, H. Li and H. Van Lavieren. 2010. Contaminants in the coastal karst aquifer system along the Caribbean coast of the Yucatan Peninsula, Mexico. *Environmental Pollution*, 159: 991-997.

Mutchler T., K.H. Dunton, A. Townsend-Small, S. Fredriksen and M.K. Rasser. 2007. Isotopic and elemental indicators of nutrient sources and status of coastal habitats in the Caribbean Sea, Yucatan Peninsula, Mexico. *Estuarine, Coastal and Shelf Science*, 74: 449-457.

Mutchler, T., R.F. Mooney, S. Wallace, L. Podsim, S. Fredriksen and K.H. Dunton. 2010. Coastal Lagoons: critical habitats of environmental change. Taylor & Francis Group, Boca Raton, FL.

Savidge, G. 1988. Influence of inter-daily and intra-daily light-field variability on photosynthesis by coastal phytoplankton. *Marine Biology*, 100: 127-133.

Schmitter-Soto, J.J., E. Escobar-Briones, J. Alcocer, E. Suárez-Morales, M. Elías-Gutiérrez and L.E. Marín. 2002. Los cenotes de la península de Yucatán. Centro de Ecología y Desarrollo, México.

Scholz, T., J. Vargas-Vázquez, F. Moravec, C. Vivas-Rodríguez and E. Mendoza-Franco. 1995. Cenotes (sinkholes) of the Yucatan Peninsula, Mexico, as a habitat of adult trematodes of fish. *Folia Parasitologica*, 42: 37-47.

Schubert, H., P. Feuerpfeil, R. Marquardt and I. Telesh. 2011. Macroalgal diversity along the Baltic Sea salinity gradient challenges Remane's species-minimum concept. *Marine Pollution Bulletin,* 62: 1948-1956.

Worthington, S.H. 2009. Diagnostic hydrogeologic characteristics of karst aquifer (Kentucky, USA). *Hydrogeology Journal,* 17: 1665-1678.

Yoshikawa, T., O. Murata, K. Furuya and M. Eguchi. 2007. Short-term covariation of dissolved oxygen and phytoplankton photosynthesis in a costal fish aquaculture site. *Estuarine, Coastal and Shelf Science*, 74: 515-527.

Appendix A. List of macroalgae identified at each site: 9 cenotes and 1 reference site.
The sites are in order of increasing distance from the sea.

Type	Taxa	Akumal Bay	Yal Kú	Cenote Manatee	Xcacel Xcacelito	Laguna Lagartos	Cenote Akumak	Cenote Dos Ojos	Cenote Balam	Laguna de Cocodrilo	Laguna de Uxuxubi
Green	*Acetabularia* sp.	x	x								
	Batophora oerstedii		x	x		x	x				
	Bryopsis sp.		x	x							
	Bryopsis plumosa			x							
	Caulerpa sp.	x		x			x				
	Caulerpa sertularioides		x								
	Caulerpa verticillata		x								
	Chaetomorpha linum	x		x							
	Chara sp.				x	x	x			x	x
	Cladophora spp.	x	x	x	x	x	x	x	x		
	Dasycladus vermicularis					x	x				
	Derbesia sp.	x	x	x							
	Desmid sp.					x					
	Halimeda spp.	x	x	x							
	Microthamnion sp.				x			x			
	Penicillus spp.	x	x								
	Rhipocephalus phoenix	x									
	Rhizoclonium riparium		x				x				
	Spirogyra sp.			x		x	x			x	x
	Tribonema sp.							x	x	x	
	Udotea spp.	x	x								
	Ulva spp.		x	x	x	x	x				
Red	*Acanthophora spicifera*	x					x				
	Acrochaetium sp.		x					x			
	Aglaothamnion sp.		x	x							
	Amphiroa sp.	x	x								
	Amphiroa fragilissima		x								
	Antithamnion sp.		x								

Type	Taxa	Akumal Bay	Yal Kú	Cenote Manatee	Xcacel Xcacelito	Laguna Lagartos	Cenote Akumak	Cenote Dos Ojos	Cenote Balam	Laguna de Cocodrilo	Laguna de Uxuxubi
	Asparagopsis taxiformis	x	x								
	Bostrychia tenella					x		x			
	Bryothamnion triquetrum	x									
	Centroceras clavulatum	x	x	x							
	Ceramium sp.	x	x	x							
	Ceramium flaccidum		x								
	Chondria sp.	x									
	Crouania altenuata	x									
	Digenea simplex	x	x								
	Erythrotrichia sp.		x								
	Galaxaura sp.	x									
	Gelidiella sp.		x	x							
	Gelidiopsis sp.		x								
	Griffthsia sp.		x								
	Heterosiphonia gibbesii	x	x								
	Hypnea sp.		x								
	Laurencia poiteaui	x	x								
	Liagora sp.	x									
	Neogoniolithon spectabile	x									
	Polysiphonia sp.	x	x	x							
	Rhodymenia sp.	x									
	Trichogloepsis pedicellata	x									
	Wurdemannia miniata	x									
Brown	*Dictyota* spp.	x	x				x				
	Hincksia mitchelliae			x				x			
	Padina sanctae-crucis		x								
	Padina gymnospora	x									
	Pleurocladia sp.							x			
	Sargassum spp.	x									
	Sphacelaria sp.			x							

Type	Taxa	Akumal Bay	Yal Kú	Cenote Manatee	Xcacel Xcacelito	Laguna Lagartos	Cenote Akumak	Cenote Dos Ojos	Cenote Balam	Laguna de Cocodrilo	Laguna de Uxuxubi
	Stypopodium zonale	x	x								
	Turbinaria turbinata	x									
Cyano-bacteria	*Chroococcus* sp.										x
	Gloeocapsa sp.		x								
	Lyngbya spp.	x	x	x	x	x	x	x	x	x	x
	Merismopedia sp.					x					
	Scytonema sp.					x					
	Spirulina sp.					x					
Diatoms	*Ditylum* sp.		x								
	Lichmophora sp.		x								
	Melosira sp.		x	x	x						
	Tabellaria sp.		x		x			x			
Total	Green algae	9	12	10	4	7	8	3	2	3	2
	Red algae	18	18	5	0	1	1	2	0	0	0
	Brown algae	5	3	2	0	0	1	2	0	0	0
	Cyanobacteria	1	2	1	1	4	1	1	1	1	2
	Diatoms	0	4	1	2	0	0	1	0	0	0
	Number of taxa	33	39	19	7	12	11	9	3	4	4

Appendix B. Site Description with images.

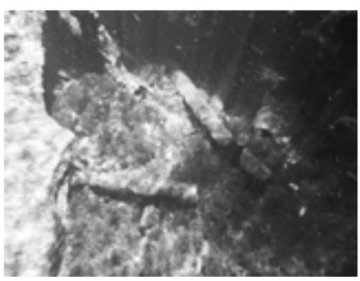
Site description

Akumal Bay
Seagrass beds consisted of *Thalassia testudinum*, *Halodule wrightii* and *Syringodium filiforme.* Green, red and brown algae was found in coral heads, seagrass beds and sandy substrate. High diversity of red and green algae.


Yal Kú
Mostly green and red algae found in inner, middle and outer sections. Brown algae higher in outer and absent in inner section. Diatoms present at inner and middle sections. Cyanobacteria present in all sections.

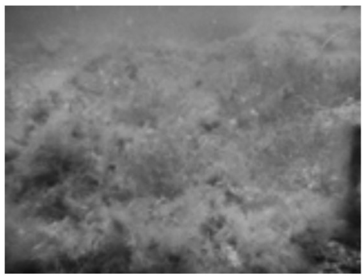

Cenote Manatee
Mostly green and red algae found in inner, middle and outer sections. Two brown algae genera sampled. Thick mats of diatoms (*Melosira sp.)* grew on mangrove roots. One genus of cyanobacteria sampled.


Xcacel Xcacelito
Dominated by green algae. Long and thick mats of *Chara* sp. grew densely on a section of the substrate. One genus of cyanobacteria sampled. Diatoms grew on mangrove roots.




Laguna Lagartos
Dominated by green algae and cyanobacteria. One species of red algae sampled. No brown algae or diatoms sampled.

Cenote Akumak
Green algae flourished in thick mats covering every surface. One species of red, brown and cyanobacteria sampled. Sampled a genus of submergible land plant.



Cenote Dos Ojos
Few algae found, most of it growing on the rocks that received sunlight.

Cenote Balam
Green algae (*Cladophora* spp. and *Tribonema* sp.) and cyanobacteria (*Lyngbya* spp.) drifted on the surface of the water, turning it into a gray color.

Laguna de Cocodrilo
Sampled only green algae and cyanobacteria. Also sampled a genus of submergible land plant. Surrounded by red mangroves.

Laguna de Uxuxubi
Under a construction project that greatly disturbs the sediment. Few algae found, sampled only green algae and cyanobacteria.

Vertical Vienna: Representations of The Occupied Metropolis in Graham Greene's The Third Man

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The deepest problems of modern life flow from the attempt of the individual to maintain the independence and individuality of his existence against the sovereign powers of society, against the weight of the historical heritage and the external culture and technique of life.

— Georg Simmel

It is the storyteller's task to elicit sympathy and a measure of understanding for those who lie outside the boundaries of State approval.

— Graham Greene

Graham Greene's *The Third Man* (1949) marks the second collaboration between the novelist and filmmaker Carol Reed. Greene explains in his preface to the book that the story was actually never meant for publication in its novel-form, but instead was supposed to serve as the narrative screenplay of the film. For the reader of *The Third Man,* as a novel the text provides an intricate representation on multiple vertical planes of occupied space in post-war Vienna and the alienating effects of state power and the modern metropolis on a civilian population. And so, a conjunctural analysis of Greene's novel with social theorists Georg Simmel (for analyses of metropolitanism and psychology) and Louis Althusser (for the relationship of the State to ideology and repression) may produce a new reading of *The Third Man* that both complicates initial assumptions about the story as a simple didactic of good (Martins) trumping evil (Lime)[2] and provides the theoretical pairing of Simmel to Althusser, each of whom offer to the other insights which generate a useful supplement to reading alienation in literary texts.

The Third Man follows Rollo Martins, a lonesome English drifter, who travels to occupied, post-war Vienna on an invitation from his childhood friend, Harry Lime. However, upon arriving in the city, Martins learns of Lime's untimely death by motor-accident the day before. Due to the suspicious circumstances surrounding his friend's death, and with the newly acquired knowledge that Lime had been accused of serious racketeering charges, Martins takes it upon himself to investigate the city, its residents (Lime's friends and associates) and the present English police force to uncover some more preferred postmortem report on his old friend. In conversation with Althusser's "Ideology and Ideological State Apparatuses" (1970) and Simmel's " The Metropolis and Mental Life" (1903), both seminal texts from each theorist, the following analyses posit that the heightened presence of the State in Vienna (occupied by four sovereign nations, which constrict the city-space, directly intervening in the lives of civilians in regard to their mobility, or lack thereof), implicit in the characters of Colonel Calloway (by repression) and Martins (by ideology), in tandem with the alienating nature of the metropolis, necessarily leads to civilians', like Harry Lime, subversion of the State (by way of racketeering) for survival. Finally, in order for the 'reproduction of the conditions of production' and the perpetuation of State domination to be realized, it is Calloway and Martins who ultimately work together to neutralize Lime (having faked his own death to avoid persecution in the first place) at the close of the novel.

To begin, we should take note of Greene's use of the narrative frame in the story, which effectively rebrands state surveillance as impartial reporting. *The Third Man* is recounted by Colonel Calloway in one of the earliest instances of Greene using the first person narrative form. Greene's choice of Calloway is significant and strategic because he proves to be the most emotionally removed from what he describes as a "strange rather sad story."[3] His personal detachment from the individuals involved and the circumstances they face is really a consequence of his professional relationship to the case. Calloway is the leading officer in the investigation of Harry Lime, and so his narrative retelling of *The Third Man* also constitutes an official's final analysis of the reports. Furthermore, Calloway must be read as a representation of the State. As obvious as this analogy may seem, it must be pushed further still. Althusser recalls Marx's foundational construction of society: the *infrastructure,* or economic base, which determines the *superstructure,* itself divided into two 'levels'—the politico-legal (law, the State) and the ideological (religious, ethical, political, etc.). From this conception Althusser categorizes the State between its Repressive State Apparatus (RSA), which functions primarily by violence (e.g. the police, military, state surveillance and security apparatuses), and its Ideological State Apparatus (ISA), which functions primarily by ideology (e.g. the family, school, church, media). If Calloway, as an agent of the RSA, is functioning predominately by violent repression in his efforts to apprehend Lime, he is also functioning, secondarily, by ideology (his conceptions of justice and peace – as ends to be reached through Lime's detention). As Althusser explains, the armed institutions of the State function by ideology "to ensure their own cohesion and reproduction, and in the 'values' they propound externally."[4] To this end, Calloway fulfills his role consistently: appealing to Martins' moral sensibilities (by revealing to him Lime's atrocities) in order to neutralize, to repress his criminal suspect.

Colonel Calloway's matter-of-fact approach to narration, even in his scenic descriptions, are, indeed, akin to reportage, and inform his realist attitude toward both war-torn, partitioned Vienna as well as Martins' volatile ethics and inane romantics (rooted in his ideological motivations). It is also Calloway who first mentions the importance of the spatial politics of Vienna to the development of the story. Early in the text, Calloway remarks that in order to understand the case of Harry Lime one "*must* have an impression at least of the background."[5] Calloway's descriptions of Vienna are clear-cut, yet detailed: the "smashed dreary city"[6] is divided into four zones, which are occupied by the French, Americans, Russians, and British. The center city, or Inner Stadt, however, is under the control of all four powers, which rotate the responsibility of supervision and security every month. Calloway does not participate in other romanticizations of Vienna - stating that he never knew it between the wars, and certainly cannot remember the old Vienna "with its Strauss music and its bogus easy charm."[7] This disposition is crucial to Calloway's detached, realist perspective on the circumstances of the plot, and reaffirms his place within the primarily repressive wing of the State, which does not function foremost by ideology. Nostalgia for Vienna's pre-war(s) period is futile to him. The reverse is a common symptom of what is often called *the myth of the city,* wherein the supernatural, idealizations of sentimental places are superimposed on the consciousnesses of inhabitants and visitors alike, whom remain ignorant to the truly imperfect, sometimes dire states of the said localities' reality. [8] Avoiding this indulgence, claiming not to have "enough imagination," Calloway claims "to me [Vienna] is simply a city of undignified ruins which turned that February into great glaciers of snow and ice."[9] Thus, within Greene's portrayal of Calloway lies a strategic balance between a predominately pragmatic authority figure and a less influential ideologist.

It is within Greene's narrative frame through Colonel Calloway that the reader begins the notice the significance of space and spatial relations in post-war Vienna. While retracing the story, Calloway is careful to consistently note, in parentheticals to the reader, the zones in which activities occur. Calloway's insistence on the significance of site-specificity to the individuals' (mainly Martins') actions ultimately provides the reader with brief descriptions of each sovereign zone early on in the story. Greene supplies comical characterizations of each zone representative of its mother country: the American zone cannot be mistaken by virtue of its abundance of ice-cream parlors, while the Russian zone within the cemetery is marked by "huge statutes of armed men," and the French, by "rows of anonymous wooden crosses and a torn tired tricolor flag."[10] These characterizations are further exaggerated later in the story during Anna Schmidt's (Lime's ex-lover) detention, wherein, while Anna is dressing, the Russian "watched the girl all the time, without a flicker of sexual interest; the American stood with his back chivalrously turned; the Frenchman smoked his cigarette and watched with detached amusement the reflection of the girl dressing in the mirror of the wardrobe; and the Englishmen stood in the passage wondering what to do next."[11] These sections, again, reinforce the significance of space and the politics behind the site-specificity of scene in the story.

Greene's narrative mode, by way of Colonel Calloway's first person recountance, thus exhibits the realist, detached viewpoint, which presents the facts of the story in a supposedly impartial manner. This viewpoint, however, is ultimately the viewpoint of the State, which is only impartial up to the point wherein its hegemony is threatened. Calloway's making slight of Martins until he proves to uncover viable new evidence to Lime's case is evidence of his disinterest in ideological domination. Calloway never veers far from connecting events to their spatial context; it is this spatial contingency in *The Third Man* that further determines the activities of Rollo Martins, a stranger to the occupied city. Greene casts Martins as the romantic brute newly arrived in Vienna, trying to discern its rhythms and functions all the while attempting to reason with the alleged loss of his childhood friend, Harry Lime. Martins' movements through Vienna are those of an alienated foreigner or tourist. However, this alienation is not only from the city, but also from the knowledge of what has become of Lime. If Calloway represents the detached eyes of the State, functioning secondarily by ideology, then Martins assumes the role of the ideological institution. Martins is hopelessly attached to his fraternal memories of Lime, to the point wherein his actions are predominantly motivated by nostalgia and a quest for justice. Lime threatens Calloway's authority and disrupts the reproduction of the means of production through his involvement in a racket-market, and thus represents to Calloway only a subversive element which must be eliminated.

In stark contrast to Calloway's perspective of Lime, Martins' viewpoint allows a certain realist/romanticist dialectic to form between the two men (as well as with Anna Schmidt, also a realist). In their initial conversation about Lime, Calloway notes that Martins "looked at Lime's image from a different angle or in a different light."[12] This dialectic is fully realized, however, between Martins and Anna later on in the book when Martins reveals the truth of Harry's criminal activities (disclosed to him by Calloway earlier). Although Martins is finally confronting the reality of Lime's behavior he is treating it ideologically through his romantic memorial projections of his infallible best friend. Anna, however, provides him with the necessary foil: "For God's sake stop making people in *your* image. Harry was real. He wasn't just your hero and my lover. He was Harry. He was in a racket. He did bad things. What about it? He was the man we knew."[13]

The desperate reality of Vienna, that of the military occupation and economic stagnation, produces a civilian alienation that necessarily determines the emergence of criminal, subversive behavior – the emergence of a racket market. The counterintuitive negation of 'peace' caused by the excess presence of the four-way Repressive State Apparatuses (RSA), explicitly and consistency referred to by Calloway, is a sophisticated commentary by Greene. Indeed, the stasis of humanist faith leads not only Lime into racketeering, as, according to Kurtz (one of Lime's associates), "everyone in Vienna is [in the racket]."[14] In "The Metropolis and Mental Life," Georg Simmel investigates "the adaptions made by the personality in its adjustment to the forces that lie outside of it."[15] The most modern form of conflict, according to Simmel, is the antagonism caused by the sovereign powers of society against the individual. The antagonisms of four occupier nations against civilians in Vienna lead to the "resistance of the individual to being leveled."[16]

Vienna at the ground level (in some areas reconstruction of the city is limited to only the 1st floor) is much like Kurtz's smile at the end of chapter four. A native Austrian, and therefore limited in his access to sections of his own hometown (Sacher's, for instance), Kurtz bids Martins a farewell with a "Viennese smile," charming, yet brittle. Martins notices in Kurtz that "one hand smoothed the toupee, while another, passing softly over the mouth, brushed out the smile as though it had never been."[17] From the ground level, however, the reader is still inclined to trust in liberal ethics, the necessity of military occupation and root against Lime and his cronies. This conviction is called into question in the following section, wherein, high above the city on the Great (Ferris) Wheel, Martins is reunited with Lime (having falsified his death).

Greene's use of the higher altitudes as the plane for deliberation between the old friends is strategic as Lime and Martins are reunited on a tense ride in the Great Wheel. The characters and the reader are transferred literally and figuratively away from the ground level of Vienna. This distantiation from the "strange rather sad" circumstantial reality of the pedestrian view of Vienna provides the characters and reader a clarity of perspective and opportunity to hear Lime's case. With Vienna, a "toy landscape," below Martins confronts Lime, for the first time "without admiration,"[18] with the accusations. Lime's response is fairly clear, cynical as it may be: "In *these days*, old man, nobody thinks in terms of human beings. Governments don't, so why should we?"[19] Lime is the archetypal model of Simmel's *metropolitan type*: "Instead of reacting emotionally, the metropolitan type reacts primarily in a rational manner, thus creating a mental predominance through the intensification of consciousness, which in turn is caused by it."[20] Simmel is correct in his identification of the metropolis as the seat of money economy, which causes the individual (in his efforts for survival) to function under a "formal justice" and "unrelenting hardness." Lime puts forth the logical deduction that if governments function by violence, which is packaged in ideology, in order to survive, so, too, must the individual. When Martins counters his claim from a purely ideological standpoint on the ethics of the matter, as many innocent people were killed through Lime's racket, Lime retorts in a blasé tone, pointing at the tiny pedestrians walking below the wheel: "Would you really feel any pity if one of those dots stopped moving – forever? If I said you can have twenty thousand pounds for every dot that stops, would you really, old man, tell me to keep my money – without hesitation? Or would you calculate how many dots you could afford to spare?"[21] Here we see Lime's "mental dullness" prove Simmel's claim that, in the alienating context of the metropolitan setting, "money takes the place of all the manifoldness of things and expresses all qualitative distinctions between them in the distinction of 'how much.'"[22] This point is reciprocated by Althusser when he states, in his elaborations on *infrastructure* and *superstructure*, that "the determination in the last instance of what happens in the upper 'floors' (of the superstructure) by what happens in the economic base."[23]

Lime's defense speaks directly to the point that, counter-intuitively, State repression and metropolitan alienation lead to a civilian subversion for survival. Furthermore, when Lime establishes his own sustainable racket-economy outside the State system (which does not contribute to the reproduction of the conditions of production), his immediate elimination is ordered by the RSA, under auspices of ideology.

At the climax of the story Martins chases Lime into the sewers of Vienna, wherein Lime, against the ideological discernment of Martins, fires a shot at his *old* friend. Any remaining sentimental relation between the men at this point disappears and the narrative devolves into a parley for immediate survival. Here in the subterranean, friendly associations and ideological presuppositions are rendered moot, allowing Martins to use full violence against Lime (which he hitherto, imagined unthinkable). However, recalling Althusser's claim that "there is no such thing as a purely ideological apparatus," we see that Martins works under the guidance of Calloway and the State to apprehend Lime. Martins fires a shot, clipping Lime, though not fatally. Lime finds the energy to try and climb up to the light of a manhole and whistle a tune, which Martins is familiar with from childhood. Both acts signify Lime's attempt to correct the circumstances: through the manhole is escape not only from the violent, affectless subterranean but also escape toward the ideological ground level of Vienna, while the tune is an appeal to Martins' nostalgia for the past rendition of Lime. However, the gesture (unlike its earlier implementation by the Great Wheel)[24] fails to invoke "excitement"[25] in, and is certainly not reciprocated by, Martins. When Martins finally catches up to him he delivers the final fatal shot to his former friend. Although not in cold blood, the act is a gruesome execution. In the beginning of the novel, at Harry Lime's first funeral, the soil at the cemetery is frozen soil. Electric drills were summed to break the earth as Calloway remarks, "[i]t was as if even nature were doing its best to reject Lime."[26] After his execution in the sewer "[a] thaw set in… the snow melted," and Lime was placed into the earth with ease.[27] Greene's play with the subterranean and its permeability here seems to put forth too simple a good/bad dichotomy. If we take seriously Greene's own personal politics as a long-time committed anarchist and attempt to understand his characters who lie outside the boundaries of State approval, we may be better able to problematize simplistic *good trumps evil* readings of the novel. Lime's actions are objectively deplorable, but *The Third Man* might more interestingly be interpreted as the critique of the State and its production, regulation, and repression of space and mobility, as well as the alienating effects of the metropolis on the individual. The alienation that follows such a complicated apparatus is unequivocally where the plot of the novel is derived.

Endnotes

1. Greene explains in his preface to the novel: "To me it is almost impossible to write a film play without first writing a story. Even a film depends on more than plot, on a certain measure of characterization, on mood and atmosphere..." Graham Greene preface to The Third Man, by Graham Greene (New York: Penguin, 1999), 7-8. (my emphasis)
2. Writing in 1985, Steve Vineberg cites as one of The Third Man's major themes "the nature of personal and social responsibility," and refers to Rollo Martins as the story's heroic figure. Steve Vineberg, "The Harry Lime Mystery: Greene's Third Man Screenplay," College Literature 12 (no. 1: 1985), 33.
3. Graham Greene, The Third Man (New York: Penguin, 1999), 14.
4. Louis Althusser, On Ideology (New York: Verso, 2008), 19.
5. Greene., 14.
6. Ibid., 14.
7. Ibid., 14.
8. See Elias Khoury's article on the status of Beirut in the 1990s after Lebanon's 15-year civil war, after which the city witnessed a massive international effort at reconstruction. According to Khoury, this effort ultimately fails as "[t]he huge machine that is reconstructing and regenerating the city is already wiping out the memory of old Beirut..." Elias Khoury, "The Memory of the City," Grand Street 54, Space (1995), pp. 137-142.
9. Greene, 14-15.
10. Ibid., 22-23.
11. Ibid., 121-122.
12. Ibid., 29.
13. Ibid., 144-115.
14. Ibid., 47.
15. Georg Simmel, "The Metropolis and Mental Life," Georg Simmel: On Individuality and Social Forms ed. Donald N. Levine (Chicago: University of Chicago, 1971), 325.
16. Ibid., 324.
17. Greene, 49.
18. Ibid., 136.
19. Ibid., 139.
20. Simmel, 326.
21. Greene, 136-137.
22. Simmel, 330.

23. Althusser, 9. This point is further complicated by Althusser later, when he discusses the possibility of a "relative autonomy" in the superstructure.
24. Before Martins sees Lime at their meeting by the Great Wheel he hears a familiar tune whistled by Lime: "Was it fear or excitement that made his heart break—or just the memories that tune ushered in…" Greene, 134.
25. Ibid., 134.
26. Ibid., 13.
27. Ibid., 156.

References

Althusser, Louis. On Ideology. New York: Verso, 2008.

Greene, Graham. The Third Man. New York: Penguin, 1999.

Khoury, Elias. "The Memory of the City." Grand Street 54. Space (1995). pp. 137-142.

Simmel, Georg. "The Metropolis and Mental Life." Georg Simmel: On Individuality and Social Forms. ed. Donald N. Levine. Chicago: University of Chicago, 1971. pp. 324-339.

Vineberg, Steve. "The Harry Lime Mystery: Greene's Third Man Screenplay." College Literature 12. no. 1: 1985. Pp. 33-44.

Geographies of Distinction: A Study of Space, Visibility and Upper Middle Class Identity in Texas

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Abstract

Sociological research has often found that the identities of the upper middle class are similarly circumscribed across different geographies. In recent years, it has been further suggested that upper middle class people are today becoming "placeless" as economic neoliberalism, understood as "globalization," fosters upper middle class cultural unity. However, a qualitative comparative analysis reveals that upper middle class identities are strongly impacted by geography. Focusing on practices of distinction and symbolic violence, this study relies on 21 in-depth interviews to examine the relationship of space and visibility to practices of upper middle class boundary work and identity formation.

An elite of cultural gatekeepers, the American upper middle class tends to define itself by aligning with ambition, dynamism and conflict avoidance (Gans 1967; Baumgartner 1988; Brooks 2000; Brooks 2004; Florida 2005). Upper middle class people tend to control the allocation of many of the resources most valued in advanced capitalist societies, and mass media constantly offer upper middle class people as moral and economic models to members of other classes (Lamont 1992). Additionally, the upper middle class tends to be dominant in areas such as fashion, art and cultural reproduction (Lamont 1992). In the United States, most scholars agree the American upper middle class also places particular emphasis on economic wealth because of the importance of socioeconomic mobility in the "American dream" (Bourdieu 1984; Lamont 1992).

In recent years, some have asserted the American upper middle class is homogenizing into a trans-national capitalist class as "economic neoliberalism" spurs a sense of new cosmopolitanism (Sklair 2001; Florida 2005; Hopper 2007). Increasingly, scholars suggest upper middle class identities are being practiced as placeless in globalizing "centers" and "peripheries" (Lamont 1992; Wallerstein 1996). Johanna Bockman (2013) writes that, "'Neoliberalism is both an approach to government and a defining political movement today." In the geographic sense, it describes the increasing "globalization" of capital and labor as financialized economies erect "global cities" alongside vast geographies of "underdevelopment." (Stiglitz 2002; Florida 2005; Hopper 2007). "New cosmopolitanism," on the other hand, can be understood as emerging norms of liberal multiculturalism that entail new forms of class-based distinction and social "Othering" in globalizing societies (Brennan 1997).

With such an influx of capital and culture today, it would be natural to assume "new cosmopolitanism" prevails in most, if not all, globalizing upper middle class communities (Brennan 1997; DiMaggio 1997; Bourdieu 1998; Sklair 2001; Hopper 2007). However, since research on the lives of well-to-do Americans remains sparse, little exists in the way of ethnographic data on upper middle class identity. This article seeks to fill those gaps in the literature using a qualitative comparative analysis. This research is vital to understand the ways in which symbolic violence continues to perpetuate class-based distinctions in advanced capitalist societies (Bourdieu 1984).

Urban geography will be compared with suburban geography to elicit a comparison of how space interacts with upper middle class identity in each context. To do this, I interviewed members of two upper middle class communities with different geographies both formed by globalization: the cityscape of downtown Austin, Texas, and the suburban sprawl of west Plano, Texas. I operationalize the practice of creating upper middle class identities by using the concept of boundary work. I define boundary work as identity formation based on demarcations of social insiders and outsiders (Lamont 1992).

Literature Review

Prevailing sociological explanations of boundary work offer a number of accounts for the motivations behind upper middle class practices of distinction. Conflict theorists suggest the upper middle class defends its values with the goal of collectively advancing its investments against the pressures of the classes below and above it (Bourdieu 1984; Habermas 1991). Individual upper middle class people then accomplish this by using different forms of capital to engender the symbolic domination of their class practices, or, *habitus* (Bourdieu 1984; Lamont 1992; Brooks 2004). "Tool kit" theorists have emphasized that culture does not determine how people perform boundary work and instead provides agents with a range of options to enact their own choices (Swidler 1986). To the contrary, interactionist and urban sociologists contend the geographic dispersal or centralization of institutions in rural areas, cities and suburbs creates spatial pressures for interaction that alter how upper middle class values are practiced (Redfield 1947; Tönnies 1963; Simmel 1950; Simmel 2012). In these accounts, urban areas are described as heterogeneous melting pots that pressure the upper middle class to accommodate with other groups, while suburbs are described as homogenous zones where the upper middle class consolidates its practices without challenges (Gans 1967; Baumgartner 1988). An additional perspective finds that upper middle class people attempt to assert their symbolic investments through various types of capital, but to do so they must make their investments visible (Benjamin 2006; Veblen 2007).

These accounts are insufficient to explain the data from my study. According to my interviews, upper middle class habitus differed between cities and suburbs. First, habitus involved various forms of wealth and boundary transgression in Austin, but involved economic capital and boundary production in Plano. Second, while urban participants were more apt to produce boundaries collectively than the suburbanites when policing strangers, neither sample reported a significant amount of interaction or accommodation to heterogeneous groups. As a matter of fact, suburban Plano is more economically and racially diverse than downtown Austin (Census 2010). Finally, visibility appeared to play a role in securing symbolic investments, but it was used for two separate maneuvers: 1) between upper middle class people themselves and civil society, and 2) between upper middle class people the non-citizen "Others" below them.

I will put forward a different solution based on my data. I believe that the *visibilities* created by different geographies, combined with the distribution of capital for distinction, offer the best explanation for why upper middle class identities diverge.

Methodology

Funded by an undergraduate research scholarship from the University of Texas at Austin, I traveled between Austin and Plano during the summer of 2013 and conducted 21 interviews in both towns during the months of August and September. All participants gave informed consent by signing a printed form. As stipulated in the consent form, pseudonyms have been used for all participants in this study.

Interviews were recorded via audio recorders and typically averaged around forty minutes in length, with some lasting as short as twenty minutes and others nearly two hours. I used semi-structured interviews to maintain topical standardization, but left a wide berth of flexibility for participants to discuss topics with me that they deemed important. Participants in Plano and Austin were found using snowball sampling. In Austin, the Downtown Austin Neighborhood Association (DANA) placed a call for my research in their September 2013 newsletter after I inquired if one of their members would like to participate in my study. This resulted in several participants contacting me, although I avoided making use of additional DANA functions to avoid oversampling persons affiliated with the neighborhood group.

I interviewed 12 participants in Plano and 9 participants in Austin. In both samples I took into account citywide and ZIP code data to develop the racial, gendered and economic diversity necessary to provide a minimally representative frame for each city. Participants in both areas were engaged in high-income occupations and were drawn from within or in close proximity to comparatively wealthy ZIP codes where mean household income exceeded $100,000 (Census 2010). I partially transcribed all interviews based on coded themes once data collection was complete. Participants' accounts were analyzed on their content, tone, use of words and pauses, and other recurring patterns. After all interviews were transcribed, the audio recordings were deleted.

Findings

Housing a sizable upper middle class population engaged in business, science and the arts, Austin has long been a center for the public sector and higher education in Texas (Census 2010). The city is a regional locale for recreation and serves as both the state capital and home to several universities. In the last quarter of the previous century, these spaces have been rapidly transformed to accommodate an emergent information technology sector and entertainment industry. These industries were attracted to the city by its quality of life, friendly public subsidies and educated work force.

The current geography of urban, downtown Austin is a recent development of the city's "growth machine" (Swearingen 2010). As the population increased from 345,890 to 842,750 between 1980 and 2013 (City of Austin 2013), developers pushed for a slew of new high-rises, restaurants, coffee shops, bars and hotspots alongside existing parkland in the city center in the 2000s (Swearingen 2010). At the same time, the population living in the urban core has not diversified. Residents are above 80 percent White and generally unmarried or single, with mean household incomes of $108,868 in downtown Austin (78701) and $140,888 (78703) in the area between downtown Austin and the Mopac Expressway (Census 2010). Some of these incoming residents have also arrived in neighboring East Austin, where conflicts between historically low-income Black residents and incoming high-income White and Hispanic residents have consolidated into gentrification (Matthews, Karen and Adams 2007; Walsh 2008).

Boundary Transgression and Boundary Making

Austin participants tended to practice upper middle class citizenship by entering public spaces and using visibility to transgress boundaries usually imposed by class differences, i.e., those of economic capital. In these spaces, Austin participants could then embody and convert various forms of capital towards their own benefit. However, not all distinction occurred the same way, and Austinites used vastly different methods of distinction for strangers outside the realm of civil society.

Nicky, a 61 year-old White female, identified public and semi-public spaces of Austin, such as the Armadillo World Headquarters and the Shoal Creek Saloon, as the grounds on which citizenship in Austin is made. A politically involved Democratic lawyer and part time librarian, Nicky said she aligns with citizens who "Keep Austin Weird." She said she does this by occasionally traveling to a local park with friends to offer free "life advice" on any matters passers-by want to talk about. But instead of establishing boundaries, Nicky said she enjoyed transgressing boundaries by mingling with people different than herself.

> [Nicky]: I find people fascinating. I love being surprised by different... I go down to the lake to talk to strangers, so obviously I like to hear different points of view and different perspectives on the world and everything like that, but I don't like someone thrusting their perspective down my throat, and I try not to be the person who does that to others.

At the park, the visibility of "fascinating people" and the ability to "hear different opinions" allows Nicky to enjoy a sense of worldliness by seeing other Austinites in civil society. But akin to the habitus of the upper middle class, Nicky does not want to have "someone thrusting their perspective down [her] throat."

Gabe, a 29 year-old White male landscape architect who remained in Austin after completing graduate school, has a similar relationship with Austin's space. Gabe lives in an apartment in downtown Austin and said he frequently takes long walks around his block to "see something new" when working or relaxing. He prefers to walk or bike to his destinations and said he also frequents music venues, cafes, coffee shops and bars in the inner Austin area on a regular basis. When asked why he enjoys being in public locales with others when he could spend his time in homes, he said he enjoyed being something like a "voyeur."

> [Gabe]: It's like going to the zoo. You get to see the Austinites in their native environment.
>
> [Interviewer]: So you do like to be seen?
>
> [Gabe]: No, no. It's a voyeuristic thing—I'm not identifying with a voyeur. I'm saying if I take someone to a specific bar, it's to show him how different people are.
>
> [Interviewer]: Do you think a lot of people in Austin enjoy that too?

> [Gabe]: I kinda' think so. I mean why else would there be so many people that are always outside at places like this? It's a Monday night, and all these people are out. They don't need to be here, it would be cheaper if they met at an apartment.

Like Nicky, Gabe is quick to say he is "not identifying with a voyeur" in asserting upper middle class status. However, he does establish his class ability to go "among the masses" and transgress the boundaries of capital as what he finds enjoyable about Austin's spaces. While he likes to be "in the crowd," he does not want to be made personally visible to others.

The coffee shop is here structurally equivalent to the space of the "Arcade," defined by Walter Benjamin in his study of Charles Baudelaire. Like the *flâneur,* Gabe enjoys long walks, seeing others consuming and the visibility of "Austinites in their native environment." Seeing others as sites of embodied educational and cultural capital, Gabe "roams through the labyrinth of merchandise as he had once roamed through the labyrinth of the city... The *flâneur* is someone abandoned in the crowd. In this he shares the situation of the commodity" (Benjamin 2006).

The owner of a coffee house in East Austin, Leonard, a 37 year-old Hispanic male, met with me at his establishment and described his coffee shop as something like an "Ellis Island of Austin." According to Leonard, the visibility of citizens and their ability to interact in public spaces allows people to transgress boundaries to become an Austinite, especially those of economic capital—if one possesses the capital to make a transition.

> [Leonard]: One of the closest friends I have is the local weatherman... knowing that guy has helped me so much. The people that he knows, I got this lease just by being his friend. Because I didn't have the financial means on paper to qualify for this, but that he knew me, that he was backing me, that he believed in me... I call it social collateral; it allowed me to do things.

While Leonard believes economic capital is not necessary to identify as an Austinite, he said living in Austin relies heavily on social capital and the ability to visibly demonstrate the social, educational or cultural capital one possesses. Leonard believes it is preferable to do this as a citizen of Austin, rather than visibly flaunting economic capital when becoming part of the city.

Unlike members of civil society, strangers were discussed by participants as significantly more susceptible to boundary work related to visibility. While upper middle class people enjoyed transgressing boundaries in Austin's urban spaces, strangers were clearly seen as outsiders, and upper middle class Austin participants voiced significant concerns over the mobility of strangers who transgressed the spaces of civil society.

Laura, a 54 year-old Hispanic female and contract manager for an Austin non-profit, is a frequent patron of coffee houses in downtown Austin. Meeting with me at one of these locations, Laura said her "coffee community" was a large part of what connected her with other Austin residents and the neighborhood she lived in (Woldoff, Lozzi, Dawn and Dilks 2013). But while she said her "coffee community" included many eclectic, educated and "different kinds of people," she also believes the coffee shops themselves segregated out certain kinds of persons from the "coffee community" of which she was part.

> [Laura]: Earlier this morning when I came in to get my cup of coffee, Larry's in his usual spot—the world is out of balance if Larry's not sitting in his spot (laughs). And next to Larry is a dark-haired man writing in Arabic. So my first thought is, graduate student at UT? My second thought is, terrorist sect? Get over it. He could just be…that's the way world is now. Maybe he's a graduate student. He could be from Houston. He could be studying Arabic, and engineering. He's not a terrorist, get over that!

The "dark-haired man writing in Arabic" was a stranger who caused Laura to question the space of the coffee shop. Laura said she does not want to jump to conclusions about the "dark-haired man writing in Arabic," but was still excited to use her social network to negotiate the boundaries made apparent by the body of this "Other" (Ahmed 2000; Ahmed 2012).

Other participants, closely connected to sources of local authority in Austin, used their connections to not only draw boundaries but also establish controls around the mobility of strangers to the city.

Ron, a 55 year-old White male and oil/petroleum businessman, lives in a loft in downtown and said he prefers to travel on foot or public transit throughout inner Austin, rarely leaving downtown except on the occasion of a business trip. Describing an encounter he had a with a homeless "refugee" from Hurricane Katrina, Ron described the boundaries he felt were between the "good actors" of Austin and the "bad actors," embodied by the Hurricane Katrina "refugees."

> [Ron]: God, those people that moved from Katrina, the Katrina people, they had to come somewhere, and I'll tell you, it really got bad for awhile. Not in my life, but downtown got bad for a while.
>
> [Interviewer]: Can you describe what happened?
>
> [Ron]: Let's see here. Well, you normally see on Congress they've got limited bus stops. They don't have bus stops on Congress and 6th Street. There's a reason. They moved a lot of the buses off Congress and put them on Brazos to break these people up, that would hang out. Those characters still do. I feel bad for anybody that's on the street, I really do, but there's no reason for them to be violent. I've seen them getting in fights, you know, just be bad actors.

Following the habitus of the upper middle class, Ron does not ascribe any natural tendencies of low moral quality or aggressiveness to the Hurricane Katrina survivors. As "bad actors," "those Katrina people" only appear on his periphery when they are "getting in fights" and *performing* as threatening to the "safe spaces" of downtown Austin. As Ron later states, he is well connected to power holders such as "[Lt. Gov. David] Dewhurst's friend" and he expects members of civil society to deputize themselves and "get a security guard" when faced with such a threat.

Another resident, Leland, shared a similar view of the need for cooperation between civil society and the state. A 49 year-old White male who recently moved to Austin for a job in the information technology industry, Leland enjoys the friendliness of Austinites, the conversations he has with cultured people, and the atmosphere of openness in the city. However, Leland iterated the importance of protecting civil society's spaces when asked about a recent drug bust in downtown.

> [Leland]: [APD] view us as an extension of their eyes and ears downtown. We have been collaborating with them through our residents, who in some cases have videotaped drug deals from their window or balcony. We have identified what we call hotspots where this activity happens, and we work with APD on informing them of these hotspots, and they therefore do undercover drug operations. I know the lieutenants and commanders of downtown on a first name basis. Art Acevedo, knows me, the chief. Downtown is the living room of Austin, so it's important that our image upholds that.

As the "eyes and ears downtown" for the Austin Police Department, Leland's social capital is crucially important for "preserving" the "living room of Austin" and keeping the crime rate low, unlike other urban centers. Knowing the "lieutenants and commanders of downtown on first name basis," Leland deputizes himself to monitor stranger's bodies, "videotaping" "hotpots" to secure the visibility necessary for establishing the proper boundaries between Austinites and the "Other."

In sum, Austin participants possessed no sole indicator of upper middle class status. They instead used visibility to convey a variety of indicators, most of which are not often associated with the broader American upper middle class. These indicators include intellectualism, educational status, cultural knowledge and social connections—an ensemble of distinctions recognizable in "new cosmopolitanism." Conversely, while generally jovial about interacting with "different people," the upper middle class of Austin deputized themselves to paralyze "Others" whom social boundaries of Austin had not properly enclosed (Wilderson 2010). Apparently, "new cosmopolitanism" includes a definite limit beyond the walls of civil society.

Space in Plano, Texas

Plano, Texas is a sprawling suburban community located north of Dallas, Texas. A "magnet community" with low corporate taxes and high property values, the suburb is home to the corporate headquarters of Frito-Lay Inc., Pizza Hut Inc., J.C. Penny Company Inc., Electronic Data Systems and a number of other national and multinational corporations (City of Plano 2013). One of the most affluent cities per capita in the United States (City of Plano 2010), the suburb has a population of 260,197 and a mean household income of

$106,266 (Census 2010). In West Plano alone, which I define as the 75093 ZIP code, the mean household income is $147,421. West Plano is the newest segment of Plano and was rapidly developed in a burst of growth in the 1980s and 1990s (Schell and Wells 2013). It is also where the majority of the Plano participants in this study reside.

Following modern trends in other well-to-do "magnet communities," Plano is racially diverse and has a population that is 59.6 percent White, 16.7 percent Asian, 14.6 percent Hispanic or Latino and 6.7 percent Black or African American (Census 2010). Much of Plano's population is not native to the suburb and is comprised largely of families attracted by Plano's opportunities for corporate employment, spacious family living, and education (Census 2010; Schell and Wells 2013). But unlike Austin, growth has resulted in a series of housing units, gated communities, athletic parks, malls and strip malls.

Economic Boundaries and Civil Society in Plano

Plano participants rarely considered themselves members of an individual community and generally described Plano as a community of individuals. Plano participants opted to produce boundaries by using the visibility of economic capital to determine the legitimacy of one's claim to upper middle class status. An enduring trend in most suburbs, the site of the home was central for practicing this visibility-heavy boundary work (Spigel 2001). Towards strangers, Plano participants used their homes as sites to surveil and prevent "Others" (Ahmed 2000; Ahmed 2012) from entering the family enclosure.

Nick, a 47 year-old Hispanic male, moved to Plano with his wife to raise children and pursue a job as a cardiologist. He has lived in Plano for 11 years but said it was difficult to define the "unique features of the suburb" given its spatial homogeneity. What was most notable about social life in Plano, according to Nick, was its emphasis on raising children.

> [Nick]: Most of these people have kids here. There's maybe one or two households that do not have kids. So we don't, interact with them as much? We don't know them. The neighbor next door to us, we're friends because they have kids in school. It's not like we live in an old neighborhood where we have like a lot of older people that live here that don't have kids.

Describing the importance of the family unit in suburbia (Miller 1995), Nick says that his own social space exists within the context of his children's lives. Nick also distinguishes a *de facto* boundary between parents who are legitimately connected to other parents, and non-parents who are effectively excluded from social life in his neighborhood. When asked about the values of people who live in Plano, Nick called attention to what he said were ubiquitous displays of economic wealth by people living in the suburb:

> [Nick]: I think here they're very particular about their cars. You see a lot more Lexus. The joke here is that there's a Lexus in every garage. So I think they value that. Their

> cars... People value how they look. Just going into a grocery store, people dress up just to go Tom Thumb.
>
> [Interviewer]: Yeah?
>
> [Nick]: In San Antonio where I grew up, they dressed in pajamas and had carriers in the store, but here, especially women I think, they're... very conscious of what they look like. For example, they're very well dressed... just at Tom Thumb.

According to Trent, a 46 year-old White male and high school football coach, this social pressure to "pass" as being upper middle class without the proper economic capital begins in the school system, where children act as avatars of consumption for signaling the relative success of a family through gauges of visible economic wealth. Trent tended to favor the "established" upper middle class of Plano who did not "need to show off their wealth" to prove they are well-to-do.

> [Trent]: Now... the interesting thing about Plano is you have—and I know its true in Austin as well—you have neighborhoods where people have wealth rather than riches. They absolutely have wealth, and they have money put away...they don't want to show off what they have, but they want to be comfortable. And some of them are leaders in the community.

Dividing Plano into residential neighborhoods associated with different levels of visible economic wealth, Trent returns to the site of the home as the visible indicator *par excellence* of success—one that can be alternatively used to signify "wealth" or "riches" depending on the legitimacy of a family's claim to class status (Spigel 2001).

Erin, a 47 year-old White female, is an example of a person with such a home. A homemaker married to a computer hardware businessman, she and her family live in a private community that is located on an airport strip. Like the rest of the residents in her neighborhood, her family owns an airplane and flies weekly from Plano to across the state and country with her private community of airplane flyers. Saying that her family was not a "showboat," Erin said her family maintained clear boundaries of friendship between those families of the upper middle class who were aware of their wealth and those who do not.

> [Erin]: Some people, I think, want to boast about what they have. But they do that by maybe driving an expensive car, because they want everyone to know that they are wealthy, that they are doing well... We have more money than most people think we have, but most people don't know that. My husband drives like a Hyundai for his business.

For Erin, the legitimacy of a claim to upper middle class status is defined by a sense of comfort with upper middle class identity and the absence of a need to "pass," an attitude that Bourdieu (1984) once articulated as established bourgeois habitus. The intimacy of

Erin's upper middle class life is only shared with other "airplane people," establishing clear boundaries against families who do not share the same status.

> [Erin]: Say softball, with my daughter: all the parents are there. I have softball parent friends and I only see them at practice at softball. Outside of that I would not call them up and say "Hey let's go eat dinner." So those are softball friends, my daughter's softball friends. My husband and I, our personal friends that we actually would call up, are the airplane people.

Erin said it was important for her to teach her young daughter this sense of class status, saying it did not "work well for her" when she was younger and communicated to her classmates that her family owned an airplane.

> [Erin]: I had to remind her that this is not normal at all. Most of the people at her school would never, ever think that they know somebody who, on the weekend, gets in an airplane to go to lunch. Their idea is to drive to Starbucks and have coffee. Our idea is to get in a plane.

Despite the apparent diversity of Plano's "magnet community," there is little chance for people living in Plano to encounter a stranger in public given the suburb's decentralized space and emphasis on impersonal automobile traffic. However, when "Others" do appear, it is the responsibility of the individual family home to monitor against the intrusion of strangers into the family enclosure. Nick described such an event in his neighborhood on the evening of Halloween:

> [Nick]: You have different waves of kids coming in during Halloween, so you have all the neighborhood kids, and then you have all the other kids that come in who are mainly kids whose parents work as landscape workers. So these dads and moms that do that, they bring their kids over. It's really funny. I've seen it happen a couple times. They come in late. What's different about them, they're so appreciative, they say thank you, [while] a lot of the kids in the neighborhood are more aggressive.

Articulated as transient and placeless, the children of the landscapers are classed and racialized outside of the upper middle class according to Nick. These children must "pass" into the space of upper middle class society through their costumes to gain entry. What appears is a binary between those "kids in the neighborhood" who are connected to Plano via their economic capital as homeowners, and the outsiders who can only appear in the din of an otherworldly night.

To protect their homes from strangers to the upper middle class, Plano participants used surveillance technology to secure their homes. In a dispute with a transient neighbor he characterized as "high" and "crazy," Trent eventually took to using video cameras to individually secure the physical boundaries of his house.

> [Trent]: He had all these cameras, and he would tell me and Ginny and Brian and the different neighbors that "Oh, I saw you did this, or I saw you whatever." Well I can play your game. So I put a camera out here. What had happened was... there's an iron rod somewhere that marks the starting point [of my property]...He wants to come in here, and broke in the gate and has got an iron rod of his own that he's put in the ground, saying now my property goes to here.

In this encounter, the intrusion of an "Other" emerged in a dispute about the boundaries of the home, signaling Trent's class status. While legal recourse remained an option for Trent in this scenario, he decided to convert economic capital into surveillance technologies because he believed it was the best way to protect the sovereignty of his "Miniature State" (Staples 2000; Katz 2001).

Denise, a 60 year-old White woman and self-employed salesperson, employed a similar "Miniature State" in her own home. Concerned about "being followed" by inner city dwellers on her business trips, Denise implemented a system of locks on her doors that require the doors to be broken down before they can be entered when locked. She said such precautions were necessary given the danger and unpredictability of crime in her community.

> [Denise]: Those apartments, there's pedophiles that live there, I have this website I look at. I don't have young children so I don't have to be concerned. There's a lot of weird stuff going on, even in the houses here. And it's not like you can have more money and it makes everything okay. It's not, "let's move into the rich neighborhood." There's just more space between the houses there.

According to Denise, no amount of economic capital can secure a reasonable distance from strangers. Though she consults with police for advice about the efficacy of security technologies, she individually takes on the responsibility of protecting her own property and welfare without the support of social networks or a local community.

So, rather than seeking "eclecticism," "diversity," and unwilling to "go amongst the crowd," Plano participants opted to focus on the microsocial lives they were able to form through their family, home and economic success. When strangers entered this enclosure, the boundary of the home became coterminous with the boundaries of the upper middle class. This alternatively-constructed civil society, far on the periphery of "new cosmopolitanism" in Austin, constructs a notably different notion of upper middle class culture.

Discussion

According to the interviews I conducted, the assumption that American upper middle class people practice boundary work the same way in different geographies is inconsistent with practices actually reported.

Living in a city or a suburb had a significant impact on the way upper middle class people practiced boundary work. In Austin, participants tended to practice upper middle class identity by using cultural knowledge, social connections, and educational capital to transgress boundaries of economic wealth in public spaces. In Plano, participants preferred to negotiate boundaries on the basis of economic wealth demonstrated through the home and family. The symbolic efficacy of these various forms of capital may be said to vary with the relative visibility of capital(s) in each space. Multiple forms of capital could be used in place of economic capital in the "Arcades" of Austin, where the upper middle class signified their status by "going into the crowd." In Plano the same task was achieved at the home and by the employment of children as avatars of conspicuous consumption (Veblen 2007).

The prevalence of capital(s) for distinction also influenced each participant's actions. In Plano, where economic capital from transnational corporations is abundant, economic capital proved the defining measure for distinction. In Austin, the influx of cultural and educational capital balanced out other measures of distinction.

Not all boundaries were based on wealth, however, and participants reacted differently when confronted with strangers in their community. While capital was the primary means of distinction in civil society, "Others" were actively excluded from the class enclosure of upper middle class space, and their mobility was subject to social control.

Two different forms of social control were used in Austin and Plano to contain the mobility of strangers outside civil society. Both varied according to the visibilities and resources for distinction at hand. Participants in downtown Austin deputized themselves to remove "Others" from the spaces of civil society by relying on social capital and networks enmeshed with state power. Deputizing themselves "eyes and ears" of the state, upper middle class people used their accumulated social networks to protect the spaces where upper middle class citizenship was made (Wilderson 2010). Thus, they individually protected the private-public "Arcades" of the city from the visible encroachment of "Other" bodies. In Plano, boundary work circumscribing strangers took place at the home. Converting economic capital into technologies of surveillance, upper middle class participants marked the boundary of the home as coterminous with the boundary of upper middle class space and produced boundaries to ensure the sovereignty of their "Miniature States" (Katz 2001).

Significance

These findings indicate that variations in visibility and capital are related to divergent upper middle class forms of citizenship. "New cosmopolitan" culture may correspond with practices of the upper middle class in Austin, but it does not correspond with the practices of upper middle class people in Plano. Both upper middle class communities have substantially different practices for what constitutes an upper middle class person *in their proper space.* For example, the hybridity, boundary transgression and transformations of capital present in Austin are nowhere to be found in Plano. Plano participants instead created economic boundaries coterminous with spatial boundaries to demonstrate their legitimacy as upper middle class. In the case of Erin, whose plane-owning family played down their economic status, economic visibility was even used negatively to avoid class conflict. The "new cosmopolitan" culture of Austin participants also had its limits. When the body of the "Other" approached Austin participants, upper middle class spaces were circumscribed through social networks enmeshed with state power. As such, inter-class conflicts over visible space tended to solidify the "fluid" identities of upper middle class Austinites.

Future Directions

It is given that a study invested in national categories, such as "American upper middle class," will overlook the porous and diasporic aspects of cultural boundaries. However, it is my hope that the use of these categories helps us understand the meaningful cultural inequalities produced in every day life. Future study will be necessary to understand how causal details of "new cosmopolitanism" diverge, e.g., visibility, the distribution of capital(s) for distinction and other factors. A future project might benefit from exploring if visibility is capable of producing cultural stratification inside the upper middle class, or in other forms of identities, such as Fraterrigo's (2008) study of hegemonic heterosexuality and urban and suburban space. It will also be necessary to broaden the range of cities being studied. With such data it may be possible to reexamine how intra-upper middle class conflicts form over what constitutes hegemonic cultural norms, an especially fruitful topic when shown that visibility can engender such different forms of upper middle class cultural practice.

References

Ahmed, Sara. 2000. "Recognising Strangers." *Strange Encounters: Embodied Others in Post-coloniality*. London: Routledge, 2000. 21-37.

Ahmed, Sara. 2012. "Speaking about Racism." *On Being Included: Racism and Diversity in Institutional Life.* Durham: Duke University Press. 141-171.

Baumgartner, M. P. 1988. *The Moral Order of a Suburb*. New York and Oxford: Oxford University Press.

Benjamin, Walter. 2006. "The Paris of the Second Empire in Baudelaire." Pp. 3-92 in *Walter Benjamin: Selected Writings.* Vol. 4, edited by H. Eiland and M. W. Jennings. Cambridge: Harvard University Press.

Brennan, Timothy. 1997. *At Home in the World: Cosmopolitanism Now.* Cambridge: Harvard University Press.

Brooks, David. 2001. *Bobos In Paradise: The New Upper Class and How They Got There.* New York: Simon & Schuster.

Brooks, David. 2004. *On Paradise Drive: How We Live Now (And Always Have) in the Future Tense*. New York: Simon & Schuster.

Bockman, Johanna. 2013. "Neoliberalism." *Contexts*, *12*. (3): 14-15.

Bourdieu, Pierre. 1984. *Distinction: A Social Critique of the Judgment of Taste.* Cambridge: Harvard University Press.

Bourdieu, Pierre. 1997. *Acts of Resistance: Against the New Myths of our Time.* Oxford: Polity.

Certeau, Michel de. 1984. "Walking in the City." Pp. 91-110 in *The Practice of Everyday Life.* Berkeley and Los Angeles: University of California Press.

City of Austin: Rosewood NPA. 2002. *Rosewood Neighborhood Plan.* Austin, Texas.

City of Austin. 2013. *Demographics.* Planning and Development Review Department. Austin, Texas. <http://www.austintexas.gov/demographics>

City of Plano. 2010. *Media Center.* Office of Economic Development. Plano, Texas. <http://www.planotexas.org/Media_Center_News_Four_North_Texas_Cities_Among_Nations_Wealthiest_1.aspx>

City of Plano. 2013. *Testimonials.* Office of Economic Development. Plano, Texas. http://www.planotexas.org/The_Plano_Story-Visionaires_EDS.aspx

DiMaggio, Paul, and Powell, Walter. 1983. "The Iron Cage Revisited: Institutional Isomorphism and Collective Rationality in Organizational Fields." *American Sociological Review.* (48): 147-60.

DiMaggio, Paul. 1997. "Culture and cognition." *Annual Review of Sociology, 23.* 263-287.

Florida, Richard. 2005. *The Flight of the Creative Class: The New Global Competition for Talent.* New York: HarperCollins.

Gans, Hebert J. 1967. *The Levittowners: Ways of Life and Politics in a New Suburban Community.* New York: Pantheon Books.

Gournelos, Ted. 2009. "Othering the Self: Dissonant Visual Culture and Quotidian Trauma in United States Suburbia." *Cultural Studies Critical Methodologies 9*. (509): 509-29.

Habermas, Jürgen. 1991. *The Structural Transformation of the Public Sphere: An Inquiry into a Category of Bourgeois Society*. Cambridge: The MIT Press.

Hopper, Paul. 2007. *Understanding Cultural Globalization.* Cambridge: Polity.

Katz, Cindi. 2001. "The State Goes Home: Local Hyper-Vigilance of Children and the Global Retreat from Social Reproduction." *Social Justice 28.* (3): 47-56.

Kawash, Samira. 1998. "The Homeless Body." *Public Culture, 10.* (2): 319-339.

Lamont, Michel. 1992. *Money, Morals, and Manners: The Culture of the French and American Upper-Middle Class.* Chicago and London: The University of Chicago Press.

Lazarus, Neil. 2011. *The Postcolonial Unconscious.* Cambridge: Cambridge University Press.

Matthews, Karen and Sarah Adams. 2007. "Gentrification Cuts With a Double Edge East of I-35." *Texas Journalist.* February 13. <http://journalism.utexas.edu/eastaustin/developmenta.html>.

McDonogh, Gary. 2006. "Suburban Place, Mythic Thinking, and The Transformation of Global Cities." *Urban Anthropology and Studies of Cultural Systems and World Economic Development 35*. (4): 471-501.

Miller, Laura. 1995. "Family Togetherness and the Suburban Ideal." *Sociological Forum 10*. (3): 393-418

Redfield, Robert. 1947. "The Folk Society." *American Journal of Sociology.* (52): 293-308.

Schell, Shirley and Wells, Frances. 2013. *Plano, TX*. The Handbook of Texas Online: Texas State Historical Association. Retrieved April 6, 2013 (http://www.tshaonline.org/handbook/online/articles/hdp04)

Simmel, Georg. 1950. "The Metropolis and Mental Life." Pp. 409-424 in *The Sociology of Georg Simmel.* Edited by D. Weinstein and K. Wolff. New York: Free Press.

Simmel, Georg. 2012. "The Stranger." Pp. 361-365 in *Classical Sociological Theory.* Edited by C. Calhoun, J. Gerteis, J. Moody, S. Pfaff, and I. Virk. Malden, Oxford and West Sussex: Wiley-Blackwell.

Sklair, Leslie. 2001. *The Transnational Capitalist Class.* Oxford: Blackwell.

Sosa, Suzi. 2007. "The East Austin Economy: Identifying, Building & Leveraging Assets for Growth." 2007 East Austin Economic Summit, PeopleFund. ACC Eastview Campus.

Spigel, Lynn. 2001. *Welcome to the Dreamhouse: Popular Media and Post-war Suburbs.* Durham: Duke University Press.

Staples, William. 2000. *Everyday Surveillance: Vigilance and Visibility in Postmodern Life.* Lanham: Rowman & Littlefield.

Stiglitz, Joseph E. 2002. *Globalization and its Discontents.* New York: W. W. Norton & Company. Lanham: Rowman & Littlefield.

Swearingen, William S. 2010. *Environmental City: People, Place, Politics, and the Meaning of Modern Austin.* Austin: University of Texas Press.

Swidler, Ann. 1986. "Culture in Action: Symbols and strategies." *American Sociological Review, 51*. 273-286.

Tönnies, Ferdinand. 1963. *Community and Society.* New York: Harper and Row.

U.S. Bureau of the Census. 2010. *Characteristics of Population*. Vol. 1. Washington, DC: U.S. Government Printing Office.

Wallerstein, Immanuel. 1996. *Historical Capitalism with Capitalist Civilization*. London and New York: Verso.

Walsh, Katie. 2008. "Small Minority-Owned Business and Gentrification: Issues, Concerns and Solutions for a Revitalized and Thriving Central East Austin Community." Undergraduate Honors Thesis, Department of Sociology, University of Texas at Austin.

Wilderson, Frank. 2010. *Red, White & Black: Cinema and the Structure of U.S. Antagonisms.* Durham: Duke University Press.

Wilson, Robert H., Rhodes, L., and Glickman, N. J. 2007. *Community Change in East Austin*. Austin: University of Texas Austin Press.

Woldoff, Rachel A., Lozzi, Dawn M. and Dilks, Lisa M. 2013. "The Social Transformation of Coffee Houses: The Emergence of Chain Establishments and the Private Nature of Usage." *International Journal of Social Science Studies, 1.* (2) 205-218.

Veblen, Thorstein. 2007. *The Theory of the Leisure Class.* Oxford: Oxford University Press.

The Infinite and the Finite: An Analysis of the United States' Energy Future

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A decade ago scientists, esteemed professors, and massive oil corporations feared the imminent decline of petroleum resources. Fears of OPEC nations in the midst of revolution, fears of another 1973 Oil Embargo, and fears of validating "Hubbert's Model of Peak Oil" stemmed the search for alternative energy. What they found shocked the nation. In 2009, shale oil and shale gas deposits were discovered throughout the United States and Canadian regions. These so called "unconventional fuels" are so vast in quantity, that in 2012, the International Energy Agency posited that the United States could become energy independent; whereby the need to import foreign energy resources could become nonessential. This Shale Gas Revolution has created much political and environmental hype and will continue to affect energy policies around the world for the foreseeable future.

Methodology: This essay will be split into four parts. The first will cover the history and definition of the Shale Gas Revolution and renewable energy. The second part will focus on the geopolitical implications that "energy independence" will have for the United States and the Middle East due to the rise in unconventional fuels. The third part will elucidate the implications the shale gas development will have for renewable energy development. The reason both of these factors will be analyzed is because they are inextricably linked to any foreign policy and domestic policy that is created within the United States—the perceived geopolitical consequences of the Shale Gas Revolution will divert investment of renewable energy towards a resource that is tried and true. However, the same geopolitical consequences (i.e. energy independence) are possible if the United States develops renewable energy. It is important to connect the geopolitical consequences of shale gas to the implications for renewable energy. This essay will end with an analysis of policy recommendations which requires changing the mentality of depleting finite resources towards implementing renewable resources for lasting sustainable development and absolute energy independence.

Thesis: As the geopolitical and environmental consequences of shale gas and renewable energy are taken into account, it is important to remember that the recent rise in unconventional fuels within the United States can only be considered temporary. Shale gas is a finite resource and it is imperative that energy policies search for cleaner, more sustainable sources of energy. In the end, unconventional fuels, like shale gas, only provide a cushion of time for the world to implement renewable energy infrastructure: it is neither a permanent strategy nor a lasting economic tactic. The goal of this essay is to provide an overview of the effects the Shale Gas Revolution will have on American geopolitics and renewable energy development. Additionally, this paper aims to provide a platform strategy to use unconventional fuels as a transitory resource towards a sustainable future.

PART 1: Background on Shale Gas and Renewable Energy

History of Shale Gas

The United States has known about shale gas since the mid-19th Century; however, shale gas was never fully developed or pursued until the beginning of the 21st Century because foreign oil and natural gas have been typically cheaper to import than domestically produce. In 2008, a global economic recession hit the United States and dramatically affected oil prices. This oil crisis harkened back to the 1973 Oil Embargo and fears of high oil prices opened the door to the domestic production of unconventional gas. The goal of the United States was to supplement foreign oil imports with domestic gas production. However, in 2009, the United States Geological Survey found massive deposits of shale gas which caused "US domestic production to rise from 50.7 billion cubic feet per day (bcfd) in 2006 to 57.4 bcfd in 2009," easily turning the tables on foreign oil.[1] And thus, the Shale Gas Revolution began. This revolution, so to speak, presents a unique opportunity for the United States to cease being a net importer of fuel and to become a net exporter.[2] The implications for such a revelation intrigued the nation. The media grasped onto the idea of "energy independence" and the politicians clung to the thought of cheap and relatively clean *domestic* energy.[3] This boom in unconventional gas has been a contentious topic of discussion due to rising uncertainty of availability, accessibility and sustainability. The next sections will define shale gas, describe production, present predictions and explain current policies in order to form a complete basis for understanding the implications shale gas has, geopolitically and environmentally.

Definition of Shale Gas

Shale gas is part of the fossil fuel family that is labeled as "unconventional" due to traditionally being considered difficult or expensive to extract. There are three forms that unconventional gases take: shale gas, tight gas and coalbed methane. This essay will focus on the exploration of shale gas. Shale gas is defined by the International Energy Agency as "natural gas contained within a commonly occurring rock classified as shale. Shale formations are characterized by low permeability, with more limited ability of gas to flow through the rock than is the case with a conventional reservoir. These formations are often rich in organic matter and, unlike most hydrocarbon reservoirs, are typically the original source of the gas."[4] Many of these shale reservoirs overlie conventional deposits, which have been extensively explored over the last 150 years; this has given the United States a head start in investigating possible shale plays.[5] "These [shale plays] include the Barnett, Haynesville, Fayetteville and Woodford shales in Texas, Louisiana, Arkansas and Oklahoma, along with the Marcellus shale that underlies portions of the states of Pennsylvania, West Virginia and New York. The past year has also seen substantial activity in the Eagle Ford shale in Texas and the Bakken shale in North Dakota."[6] This definition of shale gas explains why this fuel has not been previously exploited, however as the Age of Fossil Fuels dwindles in decline every resource has become fair game for production. Fatih Birol, Chief Economist of the IEA, stated "the era of cheap oil is over," but that doesn't mean that the U.S. is out of energy options.[7]

Production of Shale Gas

Production of shale gas requires the use of newly evolved technology, combining horizontal drilling and hydraulic fracturing (commonly known as "fracking"). "Hydraulic fracturing, developed initially in the late 1940s is used when rock permeability is extremely low, as in the case of shale gas or light tight oil. It often takes the combination of horizontal wells and hydraulic fracturing to achieve commercial rates of production. Advances in the application of these two techniques, in combination, largely explain the surge in shale gas production in the United States since 2005."[8] However, "fracking" is an intensive industrial process that tends to have "a larger environmental footprint than conventional gas development" – often producing noxious gas emissions (methane, carbon dioxide and volatile organic compounds), air pollution, seismic activity and groundwater contamination.[9] The International Energy Agency mentions in their 2012 report, *Golden Rules for a Golden Age of Gas*, that unconventional gas production often results in higher airborne emission of hazardous greenhouse gases than conventional production.[10] Regardless of this fact, shale gas is still considered a cleaner fuel to burn. However, much to the displeasure of environmentalists, large volumes of fresh water mixed with harmful chemicals (i.e. methanol, diesel, lead) are used during the hydraulic fracturing process: "each well might need anything between a few thousand and 20,000 cubic meters (between 1 million and 5 million gallons) in order to push the gas out of shale."[11] The risk of leakage into water resources as well as risk of depleting current freshwater resources to meet production needs has created plenty of "anti-fracking" sentiment. Additionally, production of shale gas has also faced constraints due to uncertainty. Shale gas was not profitable before this combined "fracking" technology because "different parts of the (generally large) shale deposits have different characteristics: small "sweet spots" or "core areas" may provide much better production than the rest of the play, often because of the presence of natural fractures that enhance permeability. The amount of natural gas liquids (NGLs) present in the gas can also vary considerably, with important implications for the economics of production."[12] This uncertainty of the exact location of "sweet spots" hindered further development of shale gas production until 2009 when funding became available for geologic research. Since then the United States "annual shale gas production has grown from 1.0 trillion cubic feet in 2006 to 4.8 trillion cubic feet in 2010. Shale gas' overall contribution to the nation's total natural gas supply is expected to grow from 23% in 2010 to 46% by 2035."[13] The implications of this significant increase will be further analyzed in the geopolitical section of this essay.

Predicted Amounts of Shale Gas

Why put so much effort into the production of a fuel that is difficult to access, locate and produce? Because the predicted amounts of fuel beneath domestic soil could provide the U.S. with enough energy for the next 230 years *minimum*.[14] Each energy corporation, oil company and international organization has their individual figures and statistics for the predicted amounts of shale gas that are recoverable in the United States for the next few decades, but they all come to the same conclusion: the short-term future is dependent upon shale gas. In the International Energy Agency's most recent *World Energy Outlook*, the "remaining technically recoverable resources are now estimated at 200 trillion cubic meters (tcm) for shale gas—this includes the latest estimates from the U.S. Energy Information Administration (EIA) for the United States: 81 tcm for tight gas and 47 tcm for coalbed methane. In total, natural gas resources amount to 790 tcm, [equaling] more than 230 years of production at current rates."[15] While the 2013 BP Energy Outlook states that "shale gas and coal bed methane (CBM) will account for 63% of North American production by 2030.

Sustained growth of shale gas raises the prospect of LNG exports from North America by 2030" (5 Bcf/d).[16] As the world population nears 9 billion people, "energy demand in developing nations (Non OECD) will rise 65 percent by 2040 compared to 2010, reflecting growing prosperity and expanding economies. According to the Exxon Mobil 2013 Outlook, global energy demand will grow 35 percent by 2040."[17]

The revolutionary discovery of shale gas will be used in the coming years to assuage this increase in demand. However, despite the excitement of finding more energy resources, it must be acknowledged that there is the risk of "uncertainty in the United States [of whether or not] the current rise in shale gas production can be increased or indeed even maintained. [Often times,] gas from shale plays have a much faster rate of depletion than gas from conventional fields."[18] Thus it is imperative that domestic energy policies continue to support production of shale gas, but also continue to fund research and development for renewable sources of energy.

History and Definition of Renewable Energy

Renewable energy, as defined by the International Energy Agency, is any energy "derived from natural processes (*e.g.* sunlight and wind) that are replenished at a faster rate than they are consumed. Solar, wind, geothermal, hydro and some forms of biomass are common sources of renewable energy".[19] Renewable energy was the first source of energy for mankind as the burning of biomass (wood and tree litter) allowed for the first *Homo sapiens* to heat their shelters and cook their food. However, since the employment of potent fossil fuels in the 18th century, renewable energy has played a minor role in modern civilization.

Renewable energy is primarily a source of domestic energy; it is rarely exported or imported to meet energy demands. Furthermore, renewable energy has always been produced for electricity or heat. Only recently has biomass (in the form of ethanol or biodiesel) or solar energy been harnessed for the transportation sector. However, these uses of renewable energy make up less than 20% of total energy usage for the last few decades in the United States.[20] Environmentally, renewable energy is advantageous in producing negligible greenhouse gas emissions, while remaining an inexhaustible resource for energy production. This is explained by the fact that "most renewable energies fall into the category of kinetic energy which uses motion to create electricity or heat; whereas most fossil fuels are based on potential energy in which energy must be released through combustion or chemical conversion."[21] This combustion or chemical conversion produces large amounts of carbon dioxide emissions, while kinetic energy is the stable production of electricity without inefficient externalities. In recent years, renewable energy has gained more leeway in the energy market due to the threat of climate change. However, renewable energy lags behind in production due to lack of investment as fossil fuels remain the more economically profitable and familiar course of action.

Production of Renewable Energy

There are multiple types of renewable resources used for energy production; however, this essay will focus on three prominent types used within the United States: solar, wind and biomass. According to the International Energy Agency, "the world relied on renewable sources for around 13.1% of its primary energy supply in 2009."[22] Compared to the United State Energy Information Administration which states that only 11% of domestic energy within the United States is generated from renewable resources.[23] In simple terms, fossil fuels account for 85% of total energy in the United States; the leftover 15% is further partitioned into hydropower, biomass, solar and wind. It is evident from these statistics that renewable energy is not the primary focus of the United States energy policy.

Regarding the production of solar energy in the United States, there are three different production methods. The first type includes the active and passive forms of solar thermal systems in individual buildings; wherein the building is designed to capture sunlight in the form of heat by strategic placement of windows and openings or through collectors using a liquid-medium. The second type uses photovoltaic (PV) panels that transform light-waves into electricity. These are the most commonly seen solar power tools and can be installed on individual buildings or in a "solar farm." The latest technological use of solar power is called the Central Solar Power (CSP) system. This system requires a "solar farm" in which parabolic mirrors or reflecting panels are placed strategically to bounce sunlight toward a central location (either a tower or tube) that concentrates the heat to power turbo-generators.[24] All of these technologies are ready for market penetration; however, due to lack of investment, development of these technologies is costly.

Juxtaposed with solar power, wind power has been a minor source of energy for hundreds of years. Windmills and newly developed horizontal wind turbines produce a substantial amount of energy each year. Texas and California are the leading producers within the United States for wind power, but this renewable source of energy still lags behind the development of fossil fuels like shale gas and tight oil. Wind is created from the differential heating of the Earth's surface by the sun; this means that it is a variable source of energy.[25] The wind does not blow every day in the same place, just as the sun does not shine at night. These intermittency issues have been the greatest hindrance to renewable energy development as a primary energy resource. However, wind power is very low-energy intensive and has the potential to compete in a fossil-fuel dominated market because of cheap production costs.

Of the renewable energy used within the United States, biomass is the most promoted and utilized. In their book, *Renewable and Alternative Energy Resources*, Smith and Taylor claim that because of its "extremely versatile nature, biomass… can be used to generate electricity, commercial and residential heating and for transportation. It has [already] surpassed hydropower as the most used renewable energy source in the United States."[26] Biofuel and biomass will be the easiest renewable resources to begin an energy transition away from fossil fuels without having to modify the United States infrastructure significantly. Like shale gas and shale oil, biomass is based on potential energy that requires combustion to create heat and energy. Combustion of biomass can emit carbon dioxide, but biomass also acts as a carbon sink—meaning it sequesters carbon as the crops grow.

This explanation for the production of solar, wind and biomass resources is to provide a basic understanding of the benefits renewable energy has. Each of these resources are essentially inexhaustible, though they may be variable as to where they can be developed. The next section will focus on the predicted amounts each of these resources could supply in the future.

Predicted Amounts of Renewable Energy

Most predictions by the United Nations Environmental Programme (UNEP) and the International Energy Agency (IEA) provide scenarios that deem biofuels as the top competitor for fossil fuels if renewable energy is radically pursued. However, there are various predictions to the extent renewable energy will play in the future. The IEA considers "energy security and diversification of the energy mix as major policy drivers for renewables. Growth of renewables generally contributes to energy diversification, in terms of the technology portfolio and also in terms of geographical sources. Use of renewables can also reduce fuel imports and insulate the economy to some extent from fossil fuel price rises and swings. This certainly increases energy security. However, concentrated growth of variable renewables can make it harder to balance power systems, which must be duly addressed."[27] In their 2012 *World Energy Outlook*, the IEA states that global electricity generation from renewable energy sources will grow 2.7 times between 2010 and 2035.[28] Other predictions by the IEA see solar and wind energy potentially providing 20% of the world's electricity, while biomass could "provide for over half of the world's energy needs by 2050."[29] The greatest obstacle renewable energy faces is initial investment and government support. Without investment or support, the inefficiencies that are typically associated with renewable energy, such as inadequate energy storage during times of intermittency, will remain in place.

United States' Energy Policies: The Unconventional and the Renewable

The current energy policies in the United States support the usage of fossil fuels, but claim to continue funding for renewable energy. This section will provide a brief overview of current energy policies within the United States to create a basis of understanding for future energy recommendations. There are three levels of policies within the United States: international, national and state. The only level that regularly executes environmental actions is the state level. Therefore, the international community may promote initiative or policies which may never be mandated by the state. For example, the United Nations' 2011 "Sustainable Energy for All" initiative "which calls for a global target of doubling the share of renewable energy by 2030"[30] or the International Energy Agency's "New Policies Scenario" which provides a list of "Golden Rules" that unconventional gas industries must comply with or lose their "social license to operate" have not been enforced by the federal or state governments of the U.S. [31] The national and state levels do not have to ratify, sign or implement any of these international policies. This was evident when the United States refused to ratify both the Kyoto Protocol to cut global carbon emissions as well as the International Union for Conservation of Nature's 2012 World Conservation Congress Resolution 90 titled "The Exploration and Exploitation of Unconventional Fossil Fuels" which called for the prohibition of producing unconventional fuels unless there are stringent measures taken to restrict harmful development and to protect the environment.[32] These international policies face the same obstacles that U.S. national policies face against State sovereignty. The decentralized nature of power within the United States means that Congress (under the advice of the EPA) could pass policies that limit environmental degradation, but it remains up to State legislature to actually implement these national policies.

Currently, the U.S. has two main renewable energy provisions that provide financial relief for solar or wind projects on a federal level. These provisions are called the Production Tax Credit (PTC) for wind production and the Investment Tax Credit (ITC) for solar production. However, there is a perpetual risk that these tax credits will not be renewed which leads investors to be hesitant in funding these projects at the possibility that they would lose in their investment.[33] This makes funding renewable energy difficult with the added difficulty that there is no overarching federal policy that promotes renewable energy. The U.S. has left these decisions up to the State Renewable Portfolio Standards which have been successful in some States to promote greater renewable development, like Texas, but have failed to morph into national energy policies that sponsor renewable advancement. E. Donald Elliot, a professor at Yale University, raises the question, "Why doesn't the United States have a renewable energy policy like those in Europe? ... The answers lie deep in our political structure and political culture, as well as our natural endowment of huge resources of fossil energy, including shale gas and unconventional oil."[34] Mr. Hamwey and Mr. Pacini of UNCTAD (United Nations Conference on Trade and Development) stated in an interview that they viewed the energy and environmental policies within the United States as not being strong. The separation between the federal government and state government weakens the strength of policies. The problem is no one knows who to hold accountable. Is it Congress's fault that there are no lasting renewable energy policies or does it fall under the State's jurisdiction? [35]

Historically, energy policies in the U.S. have always focused on maintaining a low price of energy supplies for consumers.[36] However, the United States has never had one single, holistic national energy policy. After the 1973 OPEC Oil Embargo, President Jimmy Carter's National Energy Plan of 1977 was enacted, but it was never fully fulfilled and was discarded in 1983 by the Reagan Administration which pledged the free flow of foreign oil into the United States for the next few decades. After the Rio Earth Summit of 1992, which called all nations to promote sustainable development and a 'green economy,' the Energy Act of 1992 subsequently stipulated further development of renewable energy within the United States, but "has done nothing to mandate [a full] energy transition towards renewable energy [or fully] address the concerns of climate change."[37] This is reiterated by the 2005 Energy Act which "explicitly excluded 'fracking' from the Environmental Protection Agency's (EPA) Clean Water Act (and the Safe Drinking Water Act), a clause that has become known as the 'Cheney-Halliburton Loophole.'"[38] It is evident from these few energy policies that fossil fuels are at the forefront of the United States' agenda, while renewable resources remain in the background. Thus it is not surprising that "so far unconventional gas operations in the United States have been remarkably free of restrictive regulations at federal or state levels."[39] This might change if Congress passes the 2009 Fracturing Responsibility and Awareness Chemicals (FRAC) Act which would permit the EPA to regulate hydraulic fracturing in the United States.[40] Unfortunately, there are many political hindrances to regulatory actions for unconventional fuel development because shale gas is predicted to be immensely profitable for the United States.

The following sections will use the above information to elucidate the geopolitical and environmental consequences the Shale Gas Revolution will have for the future.

PART 2: The Geopolitical Implications of the Shale Gas Revolution

Based on the aforementioned history and statistics of the Shale Gas Revolution, one of the clearest geopolitical consequences of increased domestic production in the United States is the possibility of United States' "energy independence." As defined by Tim Gould, Senior Energy Analyst at the International Energy Agency, '"energy independence" must be interpreted to mean that the United States is close to meeting domestic energy needs while importing only from the North American continent (Mexico and Canada).[41] The goal of this section is to understand how prospective and highly controversial "energy independence" will affect future trade relations with the Organization of Petroleum Exporting Countries (OPEC) as well as how the Shale Gas Revolution will affect renewable energy production. There is much debate on the effects the Shale Gas Revolution in the United States will have on the global energy market. Many agencies acknowledge that the United States will become an exporter of shale gas and tight oil, but how will this affect the oil market dominated by the Middle East and the natural gas market dominated by Russia? If the United States lessens its need to import foreign oil while producing enough oil and gas to export, what are the geopolitical implications?

The idea of energy independence is an elusive possibility of being free of foreign energy resources and attaining self-sufficiency. Lobbied around press rooms and congressional sessions since the Nixon Era, energy independence provides the United States with the chance to get out from under OPEC's foot (disputably). With the discovery of shale gas and tight oil, this possibility has become a legitimate course of action for the United States. An article in the *New York Times* states that, "with oil demand in the United States declining, output rising and increasing integration with Canada, the United States is certainly on the way to becoming 'energy less dependent.'"[42] Factually, the U.S. Energy Information Administration determines that "the net import share of total U.S. energy consumption would be 9 percent in 2040; compared with 19 percent in 2011 (the share was 30 percent in 2005). U.S. dependence on imported liquid fuels continues to decline in the AEO2013 Reference case, primarily as a result of increased domestic oil [and gas] production."[43] Tim Gould, representing the views of the International Energy Agency, believes that the United States could become energy independent in the long-term future based on declining import statistics.[44] A report done by BP Oil and Gas claims that "import dependency, measured as the share of demand met by net imports, increases for most major energy importers *except* the U.S. The import share of oil demand and the volume of oil imports in the U.S. will fall below 1990s levels, largely due to rising domestic shale oil production and ethanol displacing crude imports."[45] The possibility of energy independence is important because of the implications it has for international relations. In a report titled *Shale Gas-A Global Perspective*, KPMG affirms that,

"With shale gas deposits being found in areas that previously had no exploitable gas reserves, shale gas production could turn countries that traditionally import natural gas into producers, making them more self-sufficient with domestic supplies. Shale gas could help them become more self-sufficient. On the other hand, countries that are traditional oil and gas exporters will need to react to their changing markets. The resulting political issues could radically alter relations between countries. Shale gas will undoubtedly have important—and unpredictable—strategic implications on geopolitics and the energy industry. For example, the development of shale gas production in Europe and potential imports from the United States could help ease European reliance on Russian gas. Elsewhere, countries like the United States and China have traditionally depended on fuel imports from politically sensitive regions, constraining their foreign policy options. Abundant natural gas can help these countries gain security of supply, which could dramatically change their relationships with other nations. On the other hand, exporting countries like Canada—which could soon see its biggest natural gas customer transform into a competing supplier—will need to make huge investments in infrastructure to create new outlets for their excess supplies."[46]

All of these reports find that self-sufficiency and increased production mean that the United States will turn the energy market on its head. The IEA sees that by 2035 the United States will be the largest producer of unconventional gas, "moving ahead of Russia with about 820 bcm of total gas production, compared to Russia's production of 785 bcm."[47] Essentially, the Shale Gas Revolution will create strategic challenges for existing gas exporters (i.e. Russia, OPEC, and Canada) due to the rise of new competitors, like the U.S. Where the United States used to have limited ability to affect global gas prices, now the United States can easily affect market prices and security. This is a sizable increase in global market influence and power for the United States. Professor Alan Riley at the City University London Law

School stated in an article he wrote that, "Geopolitically, the shale revolution strengthens the United States, reduces China's energy dependence, generates a major global stimulus, which takes the Western economies off the fiscal rocks, while potentially destabilizing both the Russian Federation and Saudi Arabia."[48] These factors suggest that the consequences of energy independence for the United States are significant, but others view possible energy independence for the United States as inconsequential.

Many see the pursuit of energy independence as a moot point for the United States. For example, Dr. John Gault of the Geneva Graduate Institute believes that United States "energy independence is not terribly meaningful."[49] He hypothesized that even if the U.S. was completely autarkic, the U.S. would still care about the Middle East because the U.S. wants free flow of oil and to control oil market prices. In this increasingly globalized world, the U.S. would not back out of involvement in foreign countries just because they had the means to function autonomously. Similarly, Dr. Emily Meierding of the Graduate Institute of Geneva goes as far as to say that "there will be no energy independence for the United States."[50] Why? Dr. Meierding says that the boom in shale gas will primarily affect electricity supply. She says that the United States would still import oil from OPEC or at least from the Canadian tar sands for the automobile industry. She explicitly states that even if the United States manages to boost production of shale gas in pursuit of energy independence, we would still import foreign oil and thus there would be no dramatic change. She says that it has become a habit for the U.S. to be in the Middle East to keep oil flowing, if the United States becomes less dependent on Middle Eastern oil they would remain involved in the Middle East in order to get oil onto the market—the U.S. would become the "Mediator of the Oil Market." Likewise, Mr. Gould of the IEA states that even if the United States did become energy independent, the U.S. will still want to be involved in the Middle East, but security risk of imports decrease.[51] Michael A. Levi of the Council on Foreign Relations cautioned "that being self-sufficient did not mean that the country would be insulated from seesawing energy prices, since those oil prices are set by global markets."[52] Thus, the United States' primary goal, economically, is to maintain interregional stability and the uninterrupted flow of oil. Therefore, regardless of any perceived future energy independence, the United States will remain in the Middle East to maintain its political and economic leverage. The U.S. will continue to use its presence to minimize China's influence and support its allies, like Japan. Nevertheless, the Shale Gas Revolution will increase America's leverage in the oil and gas market as an exporter.[53] All of these perspectives on the geopolitical consequences of the Shale Gas Revolution combine into one prediction: the United States will continue to invest in unconventional fuels and will remain involved in international affairs regardless of lessened dependence on oil. Essentially, the U.S. will become more powerful in the international energy market because it will be exporting gas and increasing its financial leverage. There may be no consensus on the probability or consequences of energy independence due to the boom in shale gas, but the significance of the Shale Gas Revolution is important for future domestic and foreign policies within the United States. For example, one of the most important effects shale gas production will have for the United States is on domestic policies for renewable energy development. The following section will expand on the hypothesis that the Shale Gas Revolution will either hinder or help the development of renewable energy.

PART 3: How will Shale Gas affect Renewable Energy?

The Hindrance of Shale Gas

The Shale Gas Revolution is poised to take the stage as the newest source of domestic energy within the United States. The geopolitical consequences of this boom in unconventional fuels are only one offshoot of the total effects the Shale Gas Revolution will have for domestic and foreign policies. The other branch, which is as dramatically affected by the drilling of unconventional fuels as the oil market, is renewable energy. It has become evident from past energy policies aforementioned that the United States is primarily focused on the profitability of fossil fuels rather than the long-term protection of the environment. Thus it is clear why many environmentalists and pro-renewable energy activists believe that the rise in unconventional fuels will hinder the development of renewable energy sources and beneficial environmental practices. This threat is emphasized by a warning given by the International Energy Agency chief economist, Fatih Birol, who stated that, "Renewable energy may be the victim of cheap [shale] gas prices if governments do not stick to their renewable support schemes… A "golden age of gas" spurred by a tripling of shale gas from "fracking" and other sources of unconventional gas by 2035 will stop renewable energy in its tracks if governments don't take action."[54] Similarly, another article from the National Geographic claims that, "shale gas will retard the growth of renewable energy's share of electricity, and push off the development of carbon capture and storage technology, needed to meet more ambitious policy targets, by as long as two decades."[55] In an interview with Dr. Meierding of the Geneva Graduate Institute, Dr. Meierding states that the rise of unconventional fuels killed any policies for climate change and renewable energy. The push for funding evaporated. She says that the discovery of domestic shale gas is a huge setback for renewable energy; however, local environmental resistance to "fracking" will help renewable policies be revived. She says that investment in renewable energy requires political will and public support.[56] Renewable energy is an underdeveloped source of energy that has been traditionally pushed aside as newfound fossil fuels are continuously sought. Essentially, "the expansion of shale gas would put limits on the expansion of other sources of electricity, because natural gas power plants tend to be cheaper than wind or solar."[57] KPMG International, a consulting agency for energy investment, stated in a similar report that "shale gas has the potential to displace fossil fuels in selected locations and potentially slow the development of renewable sources… Some critics suggest that the industry's focus on developing shale gas and other unconventional sources is taking attention and resources away from the development of renewables. Low-cost power generated with abundant natural gas supplies could disrupt the economic viability of wind, solar and geothermal projects. As a result, some worry that increased shale and other unconventional gas production could delay the shift to renewables by many years."[58] In an interview with the United Nations Conference on Trade and Development department on climate change and environment, both Mr. Robert Hamwey and Mr. Henrique Pacini believe that the discovery of shale gas will set back renewable energy production.[59] However, Mr. Hamwey does acknowledge that shale gas and tight oil produce fewer pollutants and thus would be better options to coal and oil. He sees that reducing carbon emissions is a top priority for nations due to climate change, but he maintains that renewable energy will not be funded as long as fossil fuels are cheaper to produce. Akin to the affirmations of the abovementioned quotes, many environmentalists and pro-renewable energy policy activists see the development of shale gas as another episode of *Who Killed the Electric Car?* However, there is an antithesis to this discovery of unconventional fuels: there is a possibility that the rise in unconventional fuels could pave the way for a renewable energy future.

Could Shale Gas Complement a Renewable Energy Future?

The success of renewable energy depends on the policies taken by the United States in the coming years of cheap shale gas. As the United States pursues policies that would expand the production of unconventional fuels, like shale gas, it would be strategic planning to also expand renewable energy development in order to complement shale gas growth and ensure a secure energy future. This claim is expounded by the International Energy Agency who stated in their 2012 *World Energy Outlook* that,

"While renewables may compete with gas in some cases, the two can be mutually beneficial, providing low-carbon electricity while maintaining the security of electricity systems. Renewable energy is largely a domestic source of energy (although some proportion of biofuels and other bioenergy is traded internationally). When it displaces imported fuels, it contributes to greater national energy security and directly reduces import bills, which represent a fairly significant percentage of gross domestic product (GDP) in many importing countries and often contribute to a trade deficit. Biofuels have the potential to reduce these effects significantly. Moreover, greater use of renewables could indirectly put downward pressure on oil and gas prices and reduce price volatility."[60]

Likewise, Mr. Gould of the IEA does not believe that shale gas is in competition with renewable energy, although he states that shale gas is in competition with coal. He says that regardless of the Shale Gas Revolution, there has been a substantial increase in renewable energy in the last 5 years. He says this is because shale gas will, in the end, ***complement*** renewable energy due to renewable sources being rather variant (i.e. wind energy).[61] This statement aligns itself with the projections of the IEA, Exxon Mobil and BP Outlooks which repetitively state that both renewable energy production and shale gas production are expected to grow. Exxon Mobil goes further to explain that the Shale Gas Revolution is necessary to generate power during intermittent solar and wind energy production. They also believe that it is the lesser evil of all fossil fuels because it emits the least amount of carbon dioxide when burned.[62] Correspondingly, Mr. Deviah Aiama of the International Union for Conservation of Nature (IUCN) states that "if and only if renewable energy is the end goal and renewable energy policies were clearly planned would unconventional fuels, like shale gas, be able to support development of renewable energy." Shale gas could complement wind and solar energy as a backup source during times of intermittency; however, it is his view that shale gas would distract further development of renewable energy without clear renewable energy policies.[63] These claims are legitimate. Shale gas production could possibly be used to fulfill our energy needs while supporting renewable energy production, but these claims will only come to light if policies are enforced to make sure renewable energy is the long-term goal-- not forsaken, not forgotten in the face of tried and true cheap fossil fuels. The following section of this essay will provide a broad policy recommendation for the United States. This recommendation will combine the fleshed out information of current statistics and predictions of the Shale Gas Revolution and renewable energy.

PART 4: Policy Recommendation

Fossil Fuels: A Finite Resource

Amid all the hype and excitement of possible energy independence and profitability of shale gas, a very important factor is constantly ignored. Shale gas, tight oil, and all other unconventional fuels are *fossil fuels*. They are limited in supply and limited in time. Eventually, "Peak Gas" will be reached and the United States will have to revert back to searching for alternative sources of energy. It is the most logical course of action to diversify U.S. energy intake. Energy independence and security will only be achieved if the United States broadens the percentage of alternative energy (i.e. renewable energy) utilized.

Think Long Term: The Benefits of Renewable Energy

Unlike fossil fuels, renewable energy is limitless. It is an inexhaustible source of energy that has very few negative impacts on the environment. However, "in a world where there is the serious possibility of cheap, relatively clean gas, who will commit large sums of money to expensive pieces of equipment to lower carbon emissions?" [64] In reply, it is the goal of this essay to enumerate the benefits renewable energy could provide for America's energy future. For example, Hamwey and Pacini of UNCTAD state that there are a number of benefits for renewable energy that could be used as political incentives to promote development. First, and most publicized, is that renewable energy will be the most successful energy resource to mitigate climate change and carbon emissions. However, there are the economic benefits of being more labor intensive, and thus, create jobs. It also reduces waste and it connects more people to the energy grid because it is a 'decentralized' source of energy.[65] The IEA stated in their annual *World Energy Outlook* that "renewables have also been supported to stimulate economies, enhance energy security and diversify energy supply."[66] These things are valued within the political system of the United States and can be simply achieved by supporting renewable energy development. In the end, renewable energy will have the same desired outcome as the Shale Gas Revolution, and if fully supported, it will: 1) lessen U.S. dependence on foreign oil, 2) allow the U.S. to remain in the Middle East to mediate the oil and gas market, while remaining secure in domestic production, and 3) provide a market where the U.S. would be able to export biomass and biofuel profitably and easily. It is a perfect mirror to that of the possibilities seen in shale gas development, except that it is limitless in supply and time (i.e. sustainable) and is more environmentally-friendly.

Conclusion

Overall, the United States should use the Shale Gas Revolution as a cushion of time for the development of renewable energy infrastructure and technology. Seeing as shale gas will slowly transition the United States into energy security while having the added benefit of being the lesser evil of oil and coal, it could be easily used as a transitory fuel towards more sustainable energy resources, like wind, solar, or biofuels. This essay is meant to show the two main sides of the energy situation in the United States. The effects of the Shale Gas Revolution have been shown to pose geopolitical consequences for energy security and energy independence, while also creating significant environmental implications for renewable energy and environmental degradation. In order to form a comprehensive policy outline that would use shale gas development as a stepping stone for a renewable energy future, it is important to understand the current history, policies and predictions of the Shale Gas Revolution. This essay has attempted to clarify each of these subjects and, as provided, a plethora of current analysis on shale gas, renewable energy and the United States' goals of energy independence and international influence. The implications the Shale Gas Revolution has for energy security, economic leverage and renewable energy have yet to be fully understood by politicians or researchers. Nevertheless, with the combined knowledge of the geopolitical and environmental consequences, the United States could achieve lasting sustainable development if certain policies were in place to ensure a secure energy future. Shale gas is *finite*, but with its help the United States has the ability to shift the paradigm and create an infrastructure that could support an *infinite* supply of renewable energy.

Endnotes

1. Stevens, Paul. The 'Shale Gas Revolution': Hype and Reality. Chatham House, 2010. Accessed April 13, 2013. *http://www.chathamhouse.org/sites/default/files/public/Research/Energy,%20Environment%20and%20Development/r_0910stevens.pdf*.
2. International Energy Agency. World Energy Outlook 2012. Paris: International Energy Agency, 2012. Accessed April 8, 2013. *http://iea.org/publications/freepublications/publication/English.pdf*.

3. Krauss, Clifford, and Eric Lipton. "U.S. Inches Toward Goal of Energy Independence." New York Times, March 22, 2012. Accessed April 11, 2013. *http://www.nytimes.com/2012/03/23/business/energy-environment/inching-toward-energy-independence-in-america.html?pagewanted=all*.
4. International Energy Agency. Golden Rules for a Golden Age of Gas. International Energy Agency, 2012. Pg. 18, Accessed April 9, 2013. *http://www.worldenergyoutlook.org/media/weowebsite/2012/goldenrules/weo2012_goldenrulesreport.pdf*.
5. Stevens, Paul. The 'Shale Gas Revolution': Hype and Reality. Chatham House, 2010. Accessed April 13, 2013. *http://www.chathamhouse.org/sites/default/files/public/Research/Energy,%20Environment%20and%20Development/r_0910stevens.pdf*.
6. Jacoby, Henry D., Francis M. O'Sullivan, and Sergey Paltsev. "The Influence of Shale Gas on U.S. Energy and Environmental Policy." International Association for Energy Economics, v. 1, no. 1 (2012). Accessed April 9, 2013. *http://www.iaee.org/eeep/EEEP01_01_A05_Jacoby-EPUB/eeepissue.aspx*.
7. Birol, Fatih. (2009). *http://www.worldenergyoutlook.org/pressmedia/quotes/60/index.html*
8. International Energy Agency. Golden Rules for a Golden Age of Gas. International Energy Agency, 2012. Pg. 18, Accessed April 9, 2013. *http://www.worldenergyoutlook.org/media/weowebsite/2012/goldenrules/weo2012_goldenrulesreport.pdf*.
9. Ibid.
10. Ibid.
11. Ibid.
12. Ibid.
13. The University of Texas at Austin Energy Institute. Annual Report 2011/2012. Austin, TX: University of Texas at Austin, 2011. Accessed April 13, 2013. *http://www.energy.utexas.edu/images/stories/utei-annualrpt2011-12_online.pdf*.
14. International Energy Agency. World Energy Outlook 2012. Paris: International Energy Agency, 2012. Accessed April 8, 2013. *http://iea.org/publications/freepublications/publication/English.pdf*.
15. Ibid.
16. BP. BP Energy Outlook 2030. London: BP, 2012. Accessed April 13, 2013. *http://www.bp.com/liveassets/bp_internet/globalbp/STAGING/global_assets/downloads/O/2012_2030_energy_outlook_booklet.pdf*.
17. ExxonMobil. The Outlook for Energy: A View to 2040. ExxonMobil, 2013. Accessed April 9, 2013. *http://www.exxonmobil.com/Corporate/Files/news_pub_eo2013.pdf*.
18. Stevens, Paul. The 'Shale Gas Revolution': Hype and Reality. Chatham House, 2010. Accessed April 13, 2013. *http://www.chathamhouse.org/sites/default/files/public/Research/Energy,%20Environment%20and%20Development/r_0910stevens.pdf*.
19. International Energy Agency. "Renewable Energy." 2013. Accessed April 13, 2013. *http://www.iea.org/aboutus/faqs/renewableenergy/*.
20. Ibid.
21. Smith, Zachary A., and Katrina D. Taylor. Renewable and Alternative Energy Resources. ABC-CLIO, Inc. 2008.
22. International Energy Agency. "Renewable Energy." 2013. Accessed April 13, 2013. *http://www.iea.org/aboutus/faqs/renewableenergy/*.
23. United States Energy Information Administration. Annual Energy Outlook 2013. U.S. Energy Information Administration, 2012. Accessed April 9, 2013. *http://www.eia.gov/forecasts/aeo/er/executive_summary.cfm*.
24. Smith, Zachary A., and Katrina D. Taylor. Renewable and Alternative Energy Resources. ABC-CLIO, Inc. 2008.

25. Ibid.
26. Ibid.
27. International Energy Agency. "Renewable Energy." 2013. Accessed April 13, 2013. *http://www.iea.org/aboutus/faqs/renewableenergy/*.
28. International Energy Agency. World Energy Outlook 2012. Paris: International Energy Agency, 2012. Accessed April 8, 2013. *http://iea.org/publications/freepublications/publication/English.pdf*.
29. Smith, Zachary A., and Katrina D. Taylor. Renewable and Alternative Energy Resources. ABC-CLIO, Inc. 2008.
30. International Energy Agency. World Energy Outlook 2012. Paris: International Energy Agency, 2012. Pg. 212, Accessed April 8, 2013. *http://iea.org/publications/freepublications/publication/English.pdf*.
31. International Energy Agency. Golden Rules for a Golden Age of Gas. International Energy Agency, 2012. Accessed April 9, 2013. *http://www.worldenergyoutlook.org/media/weowebsite/2012/goldenrules/weo2012_goldenrulesreport.pdf*.
32. IUCN. World Conservation Congress: Resolutions and Recommendations in Jeju, Republic of Korea. Gland, Switzerland: IUCN, 2012. Accessed May 2, 2013. *https://cmsdata.iucn.org/downloads/resolutions_and_recommendations___in_english.pdf*.
33. Ramanathan, Shalini. "Renewable Energy Development: Joys & Challenges," RES Americas. Austin, TX. November 11, 2013. Presentation.
34. Elliott, E. Donald. Why the United States Does Not Have a Renewable Energy Policy. Washington D.C.: Environmental Law Institute, 2013. Accessed April 13, 2013. http://www.cov.com/files/Publication/ce0ce0e2-1d8b-4ef4-8dd9-5bffa4af86f8/Presentation/PublicationAttachment/5b91deeb-1583-46b7-a048-624472b2d90f/Why_the_United_States_Does_Not_Have_a_Renewable_Energy.
35. Hamwey, Robert, and Henrique Pacini. Personal interview. UNCTAD, 30 April 2013.
36. Smith, Zachary A., and Katrina D. Taylor. Renewable and Alternative Energy Resources. ABC-CLIO, Inc. Pg. 5, 2008.
37. Ibid.
38. Stevens, Paul. The 'Shale Gas Revolution': Developments and Changes. Chatham House, 2012. Accessed April 13, 2013. *http://www.chathamhouse.org/sites/default/files/public/Research/Energy,%20Environment%20and%20Development/bp0812_stevens.pdf*.
39. Stevens, Paul. The 'Shale Gas Revolution': Hype and Reality. Chatham House, 2010. Accessed April 13, 2013. *http://www.chathamhouse.org/sites/default/files/public/Research/Energy,%20Environment%20and%20Development/r_0910stevens.pdf*.
40. Ibid.
41. Gould, Tim. Personal interview. IEA, 19 April 2013.
42. Yergin, Daniel. "America's New Energy Reality." New York Times, June 9, 2012. Accessed April 11, 2013. *http://www.nytimes.com/2012/06/10/opinion/sunday/the-new-politics-of-energy.html?pagewanted=all*.
43. United States Energy Information Administration. Annual Energy Outlook 2013. U.S. Energy Information Administration, 2012. Accessed April 9, 2013. *http://www.eia.gov/forecasts/aeo/er/executive_summary.cfm*.
44. Gould, Tim. Personal interview. IEA, 19 April 2013.
45. BP. BP Energy Outlook 2030. London: BP, 2012. Accessed April 13, 2013. *http://www.bp.com/liveassets/bp_internet/globalbp/STAGING/global_assets/downloads/O/2012_2030_energy_outlook_booklet.pdf*.
46. KPMG Global Energy Institute. Shale Gas - A Global Perspective. KPMG Interna-

tional, 2011. Accessed April 9, 2013. *http://www.gses.com/images/documents/shale-gas-global-perspective.pdf*.
47. International Energy Agency. Golden Rules for a Golden Age of Gas. International Energy Agency, 2012. Accessed April 9, 2013. *http://www.worldenergyoutlook.org/media/weowebsite/2012/goldenrules/weo2012_goldenrulesreport.pdf*.
48. Riley, Alan. "The Shale Revolution's Shifting Geopolitics." New York Times, December 25, 2012. Accessed April 11, 2013. *http://www.nytimes.com/2012/12/26/opinion/global/the-shale-revolutions-shifting-geopolitics.html*.
49. Gault, John. Personal interview. Geneva Graduate Institute, 22 April 2013.
50. Meierding, Emily. Personal interview. Geneva Graduate Institute, 17 April 2013.
51. Gould, Tim. Personal interview. IEA, 19 April 2013.
52. Rosenthal, Elisabeth. "U.S. to Be World's Top Oil Producer in 5 Years, Report Says." New York Times, November 12, 2012. Accessed April 11, 2013. *http://www.nytimes.com/2012/11/13/business/energy-environment/report-sees-us-as-top-oil-producer-in-5-years.html?_r=1&*.
53. Goodarzi, Jubin. Personal interview. Webster University, 24 April 2013.
54. Harvey, Fiona. "Golden age of gas' threatens renewable energy, IEA warns." The Guardian, May 29, 2012. Accessed April 11, 2013. *http://www.guardian.co.uk/environment/2012/may/29/gas-boom-renewables-agency-warns*.
55. Inman, Mason. "Shale Gas: A Boon That Could Stunt Alternatives, Study Says." National Geographic, January 17, 2012. Accessed April 11, 2013. *http://news.nationalgeographic.com/news/energy/2012/01/120117-shale-gas-boom-impact-on-renewables/*.
56. Meierding, Emily. Personal interview. Geneva Graduate Institute, 17 April 2013.
57. Inman, Mason. "Shale Gas: A Boon That Could Stunt Alternatives, Study Says." National Geographic, January 17, 2012. Accessed April 11, 2013. *http://news.nationalgeographic.com/news/energy/2012/01/120117-shale-gas-boom-impact-on-renewables/*.
58. KPMG Global Energy Institute. Shale Gas - A Global Perspective. KPMG International, 2011. Accessed April 9, 2013. *http://www.gses.com/images/documents/shale-gas-global-perspective.pdf*.
59. Hamwey, Robert, and Henrique Pacini. Personal interview. UNCTAD, 30 April 2013.
60. International Energy Agency. World Energy Outlook 2012. Paris: International Energy Agency, 2012. Accessed April 8, 2013. *http://iea.org/publications/freepublications/publication/English.pdf*.
61 Gould, Tim. Personal interview. IEA, 19 April 2013.
62. ExxonMobil. The Outlook for Energy: A View to 2040. ExxonMobil, 2013. Accessed April 9, 2013. *http://www.exxonmobil.com/Corporate/Files/news_pub_eo2013.pdf*.
63. Aiama, Deviah. Personal interview. IUCN, 2 May 2013.
64. Stevens, Paul. The 'Shale Gas Revolution': Hype and Reality. Chatham House, 2010. Pg. vii, Accessed April 13, 2013. *http://www.chathamhouse.org/sites/default/files/public/Research/Energy,%20Environment%20and%20Development/r_0910stevens.pdf*.
65. Hamwey, Robert, and Henrique Pacini. Personal interview. UNCTAD, 30 April 2013.
66. International Energy Agency. World Energy Outlook 2012. Paris: International Energy Agency, 2012. Accessed April 8, 2013. *http://iea.org/publications/freepublications/publication/English.pdf*.

Regeneration by Fragmentation along Elevation and East-West Gradient in Tropical Cloud Forest Understory Piper *spp.*

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ABSTRACT

Vegetative reproduction by fragmentation occurs in many tropical understory plants. In the Neotropics, wind and moisture from the Caribbean pass over mountains, providing optimal conditions for fragmentation in montane regions, including for plants in genus Piper. Aseasonal Atlantic sites should have more uniform moisture and increasing wind with elevation, while Pacific sites should show little seasonality, and have more moisture and wind as altitude increases. Reproduction from seeds was nearly absent along the Atlantic slope, but occurred at all sites on the Pacific slope ($c^2 = 64.4268$, $P < 0.001$, $df = 5$, $N = 450$). Lowest frequency of reproduction by fragmentation was at the lowest Pacific

elevation sampled: 69% compared to 89% at the middle and high Pacific elevations, while 99% or more on each Atlantic site. Greater fragmentation in Piper spp on the Atlantic and at higher elevations on Pacific suggests that moisture plays a larger role than wind. This could be a direct response to abiotic factors directly favoring fragmentation and/or an evolutionary response to pollinator and disperser limitations in wetter and windier areas.

Introduction

Asexual reproduction through fragmentation occurs in plants of temperate (Bush & Mulcahy 1999, Greig 1993a, Sagers 1993) and tropical forests (Bush 2000, Bush & Mulcahy 1999, Cook 1983, Greig 1993a, b; Kinsman 1990, Sagers 1993). Many tropical plants can easily fragment (Greig 1993a, b; Kinsman 1990) when debris falls from the forest canopy. Trees, branches, and epiphytes can fatally fall on seedlings (Clark & Clark 1987) and saplings (Aide 1987) while giving rise to viable fragments in many plant species (Bush & Mulcahy 1999, Kinsman 1990). Many stem and leaf fragments have the ability to generate new, adventitious roots (Greig 1993a, Kinsman 1990) and produce successful (Cook 1983) plant clones (Sagers 1993) that can live independent of the parent plant.

Vegetative reproduction through fragmentation provides adaptive means to survival for many plants (Bush & Mulcahy 1999, Kinsman 1990). Vegetative reproduction is crucial for many tropical understory plants (Bush 2000, Kinsman 1990) and the ease with which some species reproduce by fragmentation perhaps makes some individuals more specialized for certain environments than others. Fragmentation can decrease genetic variability (Bush 2000) and make individuals more prone to environmental changes (Greig 1993a, Lasso 2011). However, dominant genotypes can proliferate and cause clonal species dominance (Bush & Mulcahy 1999) in communities prone to fragmentation.

The Monteverde cloud forest located on the Cordillera de Tilarán mountain range in Costa Rica is known to have characteristics that favor regeneration by fragmentation. Strong northeast trade winds provide seasonal moisture and year round wind to the cloud forest along the continental divide (Haber 2000b). High levels of moisture increase fragment survivability (Bush 2000) while disturbance increases the frequency of vegetative reproduction in many understory shrubs (Bush & Mulcahy 1999). In the rainy season, the trade winds provide water to epiphytes in the canopy, causing them to grow heavy and often fall (Haber 2000b, Kinsman 1990). During the dry season, strong easterly winds break branches that fall to the forest floor (Kinsman 1990). Year round canopy breakage and high moisture levels (Clark *et al.* 2000) in the cloud forest favor reproduction by fragmentation in many understory species.

The Atlantic (windward) and Pacific (leeward) slopes of the continental divide differ in their abiotic conditions. The windward slope has little to no seasonality and receives almost double the rainfall compared to that on the leeward slope (Haber 2000b). Wind speeds increase with elevation on both slopes (Haber 2000b) while precipitation varies with elevation only on the leeward slope (Haber 2000b). Different abiotic conditions on each side of the divide make it the ideal place to study how abiotic conditions influence vegetative reproduction through fragmentation.

Many species in the common and easily identifiable tropical understory genus *Piper* are able to reproduce by fragmentation (Gartner 1989, Greig 1993a, b; Kinsman 1990, Sagers 1993). This is likely a result of their ability to snap at the node when subject to stress (Greig 1993a) and generate adventitious roots (Kinsman 1990). This research aims to determine how the frequency of reproduction through fragmentation varies in the tropical understory genus *Piper* (Piperaceae) because of abiotic factors, namely wind and rain. If wind is the dominant factor influencing fragmentation, vegetative reproduction in *Piper* should increase with elevation along both slopes. In contrast, if moisture affects fragmentation frequency more than wind, fragmentation in *Piper* should increase with elevation only along the Pacific slope.

Methods

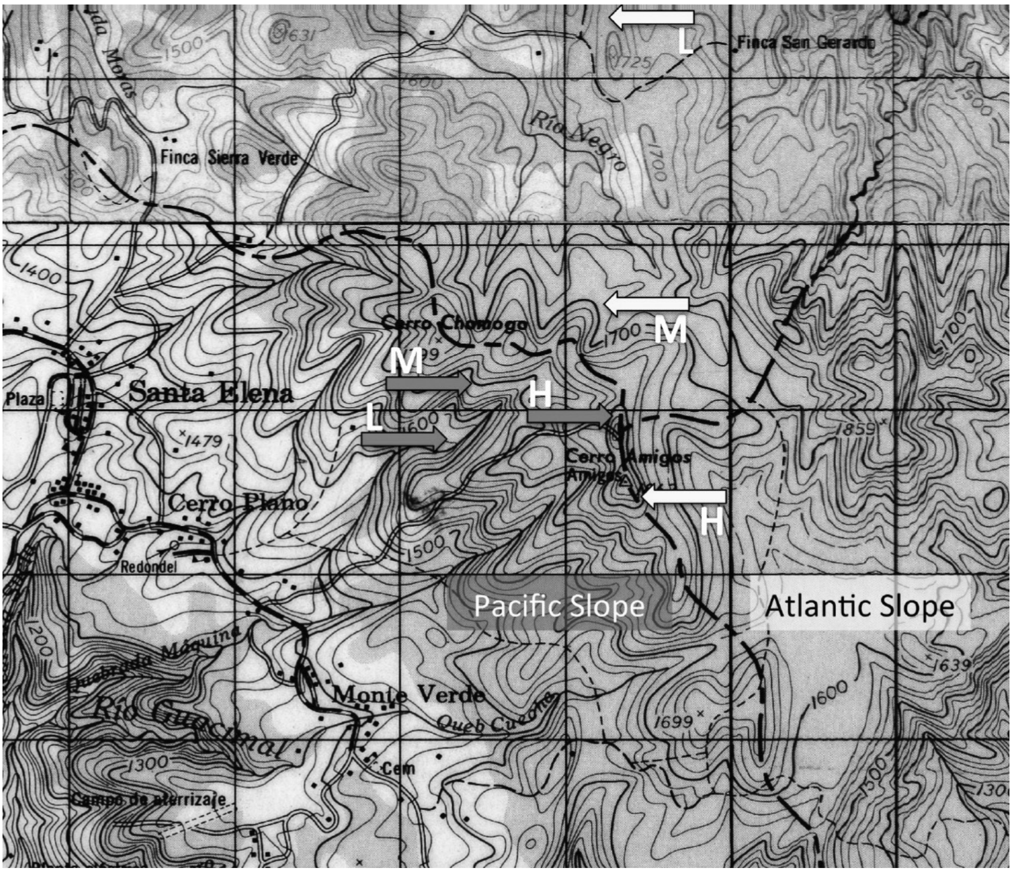
STUDY SITE.—The study was conducted on both Atlantic and Pacific slopes along the continental divide of the Cerro Amigos peak, within the Cordillera de Tilarán mountain range near Monteverde, Costa Rica. Sampling was completed from 15-27 July 2013 at six different locations.

Table 1. *Holdridge life zone classification and forest growth stage for all six sites. Pacific and Atlantic represent the Pacific and Atlantic Slopes, respectively. Forest represents forest growth stage. Key to symbols: LMWF: Lower montane wet forest; LMRF: Lower montane rain forest; 1°: primary growth forest; 2°: secondary growth forest.*

	Holdridge Lifezone		*Forest*	
Elevation	**Pacific**	**Atlantic**	**Pacific**	**Atlantic**
1565	LMWF	LMRF	1°	2°
1690	LMRF	LMRF	1°	2°
1815	LMRF	LMRF	1°	1°

Three locations were chosen along an elevation gradient on each slope of the continental divide (Fig. 1). On each slope, the highest site was placed 20m in elevation below the highest point on Cerro Amigos. On both slopes, the low, medium, and high elevation sites had elevations of 1565, 1690, and 1815 MASL, respectively. Site elevation for each site was measured at least three times using an altimeter, and the elevation of each site reported was ultimately determined by averaging all site measurements. All sites were chosen to have gentle inclines,

Figure 1. Marked map of study site locations for Piper genus sampling near Cerro Amigos peak within Cordillera de Tilarán mountain range near Monteverde, Costa Rica. Red arrows indicate Pacific slope sampling site. Yellow arrows indicate Atlantic slope sampling site. Letters L, M, H, correspond to Low, Medium and High elevation sites, respectively. Low site sampled at 1565m, Medium site sampled at 1690m, High site sampled at 1815m.



full canopy cover, and a thick understory. The Holdridge life zone classification and forest growth stage for each study site is presented in Table 1 (Haber 2000b).

Study organism—The pantropical understory genus *Piper* (Piperaceae) is commonly found throughout the tropical forest understory (Fleming 1983). In Costa Rica, the genus *Piper* consists of over 90 (Burger 1983) shade tolerant and intolerant (Lasso 2011), fast growing understory plant species (Fleming 1983). The genus is dominated by small shrubs but also includes vines and small trees (Haber 2000a). The genus is pollinated by many small insects (Fleming 1983, Semple 1974) and dispersed by a variety of bat species (LaVal & Rodríguez 2002, López & Vaughan 2007, Wainwright 2007). *Piper* spp present in the Monteverde Cloud forest can often be characterized by the presence of many of the following: (1) alternate, simple leaves; (2) swollen nodes; (3) asymmetrical leaf bases; (4) entire leaf margins; (5) terminal stipules; (6) bends or zigzags where stem exits the ground; and (7) a characteristic sweet, anise like odor on leaves (Fig. 2).

Figure 2. Characteristic features of Piper spp. All pictures are of the Piper genus. Top left: swollen nodes, bent stem near roots. Top right: simple alternate leaves, swollen nodes. Bottom left: asymmetrical leaf base, non-parallel venation, and warty appearance found in many Piper spp. Bottom right: swollen nodes with adventitious roots, bent stem.

At each of the six sample sites, 75 *Piper* spp were sampled to determine the method of reproduction for each individual. Sampling was done under a closed canopy, away from light gaps, at least 8m from the nearest trail or clearing, and no more than 5m in elevation above or below the site marker. In order to be sampled, plants must have been extending vertically less than 30cm from the ground so that the method of reproduction could be accurately determined. Vines growing terrestrially were sampled, while arboreal *Piper* vines were not sampled.

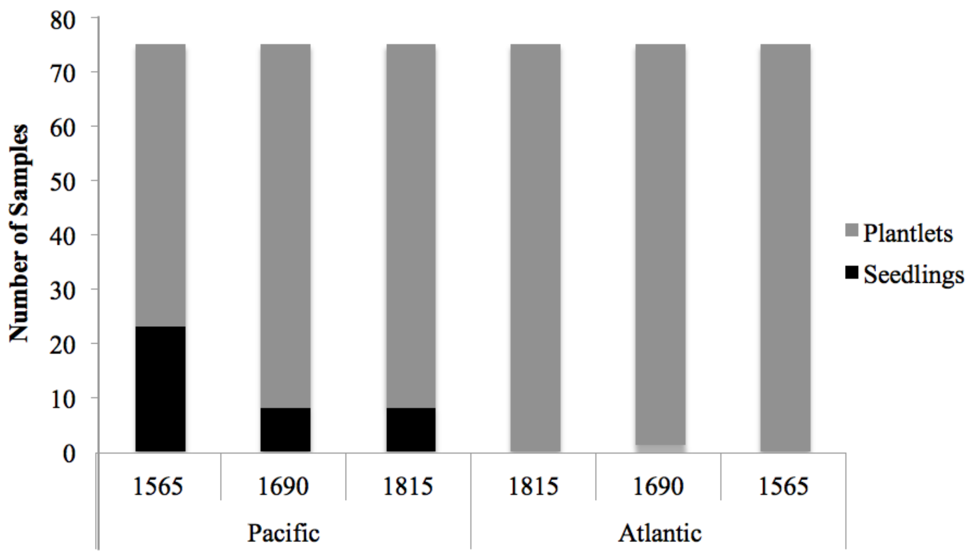
Figure 3. Characteristic features of Piper spp fragments. Top left: adventitious roots growing from swollen nodes along Piper vine. Bottom left: adventitious roots growing out of node on fragmented branch. Right: Piper spp with rotting branch fragment near root base, characteristic bent stem present near root system.

Each sample was recorded as either a plantlet or a seedling depending on its individual reproductive origin. Plantlets were defined as being products of vegetative reproduction and were easily identifiable based on vegetative growth characteristics (Fig. 3). Seedlings were said to arise from a germinating seed, and could often be easily identified by a continuous junction between the stem and root. Samples that were broken during extraction were recorded separately, but not recorded as a plantlet or seedling. Plants that could not be identified in the field were brought back for closer inspection, all of which were ultimately identified and recorded.

Results

Vegetative reproduction by fragmentation dominated reproduction in the genus *Piper*, representing over 90% of samples collected at all sites (n=450). A significant difference (c^2 = 64.4268, $P < 0.001$, df = 5, N = 450) was seen in the frequency of reproduction among *Piper* seedlings and plantlets sampled (Fig. 4).

Figure 4. Total number of plantlets and seedlings found at each sample site (n=75). Pacific and Atlantic denote slope of continental divide where samples were obtained near Cerro Amigos peak, Cordillera de Tilarán mountain range, Monteverde, Costa Rica. Values 1565, 1690, and 1815 correspond to elevations of each sample site in meters.

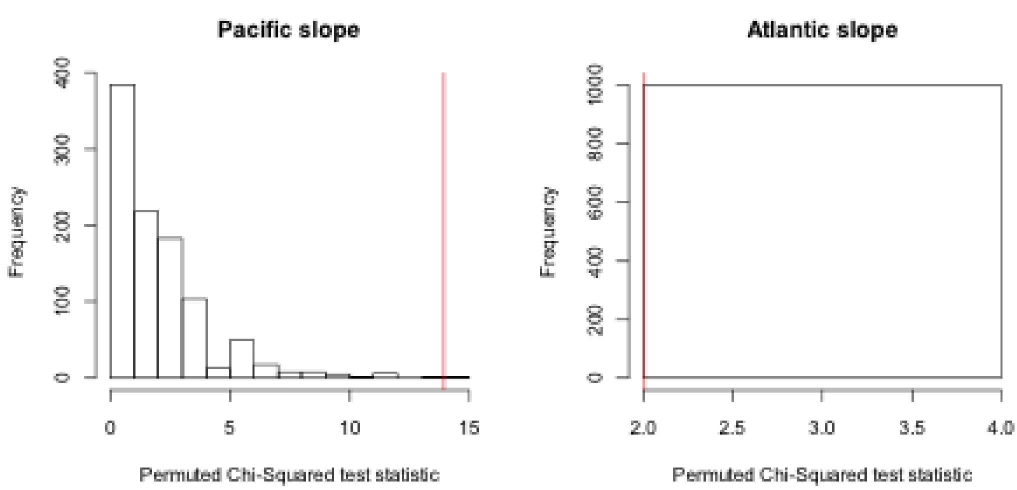


On the Pacific Slope, 83% of samples (n=186) were produced by means of vegetative reproduction. The medium and high elevation sites had the same number of seedlings (n=8), representing less than 11% of site samples. The Pacific low elevation site had the greatest number of seedlings (n=23) of all study sites, representing 31% of samples from this site. Only between the middle and low elevation Pacific sites did the frequency of fragmentation decrease, from 89% to 69%. Out of the 225 *Piper* sampled on the Atlantic slope, only one seedling was found, present at the middle Atlantic site.

The method of reproduction strongly depends on elevation on the Pacific slope (c^2 = 13.9578, $P < 0.001$, df = 2, $N = 225$). On this slope, frequency of fragmentation was seen to increase with elevation, thus *Piper* seedlings were less common at higher altitudes. A permutation of the chi-squared test statistic was performed on data from each slope to determine the likelihood of data in all possible combinations. For each slope, plantlets and seedlings were randomly assigned to one of the three elevations. A chi-squared test statistic was then computed for each iteration and compared to the observed chi-squared value. Permutation of the chi-square test statistic on the Pacific slope (1000 permutations, p = 0.004, Fig. 5) further supports the conclusion derived from the Pacific slope observed chi-squared test statistic reported above.

Fragmentation frequency on the Atlantic slope was not dependent on elevation (c^2 = 2.0089, $P = 0.37$, df = 2, $N = 225$). A permutation of the chi-squared test statistic on the Atlantic slope (1000 permutations, $P = 1$, Fig. 5) further supports the conclusion derived from the observed Atlantic slope chi-squared test statistic reported above.

Figure 5. Histograms of permuted chi-squared tests for Pacific and Atlantic Slopes along continental divide. Pacific slope observed c^2 = 13.9578, 1000 permutations, P < 0.004. Atlantic slope observed c^2 = 2.0089, 1000 permutations, P = 1. The red line marks the probability of obtaining a chi-squared test statistic at least that of the observed data if the cases were randomly assigned to the three elevation sites. A probability of <0.004 on the Pacific slope indicates a strong dependence of the mode of reproduction on elevation.



Discussion

In the Monteverde Cloud Forest, *Piper* spp reproduce primarily by means of fragmentation. The wet and windy conditions found in this elevated tropical montane region allow vegetative reproduction by fragmentation to thrive in *Piper* and many other understory plants (Bush 2000, Bush & Mulcahy 1999, Kinsman 1990, Sagers 1993). The local microclimate of each site, being a function of small-scale topographic position and exposure to trade winds (Clark *et al.* 2000), plays a critical role in frequency of regeneration by fragmentation in *Piper*. Data indicates position on upper slopes of the continental divide, exposure to trade winds, and amount of moisture received influences frequency of reproduction by fragmentation in *Piper* spp.

The two high sample sites located at the same elevation were less than 500m apart from one another. Both of these sites were observed to have the strongest winds and most understory debris compared to other elevations sampled. On the Pacific slope, northeast wind gusts are dampened by forest between the continental divide and the study site. Wind on the Atlantic slope comes unimpeded from the Caribbean as it rises up the continental divide. The high Atlantic site was observed to have the most fallen debris on the forest floor, a likely result of having the strongest winds of any site observed.

On both slopes, wind and relative amounts of understory debris were seen to decrease with decreasing elevation. Differences in observed levels of disturbance between study sites indicate that disturbance is likely a function of wind speed in high elevations of tropical montane cloud forests. Frequency of reproduction by fragmentation was similar along the elevation gradient of the Atlantic slope, signaling that disturbance alone does not greatly influence fragmentation frequency in *Piper* spp. Results and observations from both slopes indicate that wind caused disturbance is largely a result of elevation, yet disturbance is not the only condition to influence vegetative reproduction by fragmentation.

While the strong winds are believed to generate many plant fragments, these winds may also hinder reproduction by seeds. The strong winds have the power to blow tiny photoblastic *Piper* seeds (Daws *et al.* 2002, Lasso 2011) over the Atlantic slope, decreasing seed germination frequency on the windward side of the divide. The Pacific slope, being more sheltered from the harsh northeast trade winds, might allow the tiny *Piper* seeds to land and remain dormant until light initiates germination. This claim is supported by the lack of seedlings at most Atlantic sites and the presence of seedlings at all Pacific sites, with the lowest site on the Pacific having the most seedlings. In addition to strong winds carrying *Piper* seeds away from the windward slope, the lack of seedlings on the Atlantic slope might result from moisture that hinders pollination in *Piper* spp.

The overwhelming absence of seedlings found on the Atlantic slope suggests that perhaps constant, evenly distributed rain influences pollination in the genus *Piper*. While small insects have been reported to pollinate *Piper* spp (Fleming 1983), Semple (1974) found that primarily *Trigona* bees pollinate several *Piper* spp and pollination activity appeared to be related to weather. The same study reported that few *Trigona* bees visited *Piper* flowers under cloud cover, while none visited during rain. The substantial amounts of rain and clouds found on the Atlantic slope (Haber 2000b) may result in a lack of pollinator presence on this slope. In turn, the relatively large presence of seedlings at the low Pacific site and at no other site may result from increased pollinator activity because of drier conditions. It is possible that *Piper* spp on the Atlantic slope have adapted to limited numbers of pollinators by changing resource allocation to promote vegetative reproduction caused by a lack of pollinators or an increase in frequency of falling debris (Lasso 2011).

Wet and windy conditions found with increasing elevation may hinder dispersal of *Piper* fruits, further decreasing reproduction by seeds in *Piper* spp. The genus *Carollia* (Carolliinae), commonly referred to as the *Piper*-eating bat (López & Vaughan 2007), is a major seed disperser of the genus *Piper*. While one species of *Carollia* is reported to venture to elevations greater than 1500m (López & Vaughan 2007), local reports indicate presence of at least three *Carollia* spp above 1550m (J. C. Calderón Ulloa, pers. comm.). Decreased presence of *Carollia* spp at high elevations (López & Vaughan 2007) may result in disperser limitations for *Piper* at higher elevations. However, the observed presence of *Carollia* above 1550m allow for *Piper* seed dispersal at the lowest study site on each slope. The absence of seedlings on the low Atlantic site suggests that moisture may decrease *Piper* seed dispersal.

Evenly distributed rain along the Atlantic slope and decreasing amounts of rain on the Pacific slope with decreasing elevation support much of the change in frequency observed in reproduction by fragmentation in *Piper* based on fragment survivability and moisture levels. Increased levels of moisture have been correlated with success in reproduction by fragmentation (Bush 2000). Thus, the Atlantic slope appears to have optimal conditions that promote regeneration by fragmentation. In addition to fragment success, increased levels of moisture are believed to favor fragmentation by decreasing pollination and dispersal of *Piper* seeds.

Adaptations for clonal reproduction allow plants to succeed in areas where they are prone to damage from above, limited by pollinators or dispersers, or have conditions that favor asexual reproduction year round, namely water and disturbance. Even in the absence of some of these abiotic conditions, vegetative reproduction was seen to predominate in *Piper* spp within the lower montane wet forest and rain forest life zones of the Monteverde Cloud forest.

Understanding the factors that affect the method of reproduction in understory plants is critical for understanding and maintaining tropical understory diversity in cloud forests. Global warming has shown us that human action has changed, and will likely continue to change, the earth's weather. Understanding how tropical understory plants grow and reproduce is vital for knowing how abiotic factors impact genetic diversity of individual genera and the tropical community as a whole. Moreover, knowledge of how abiotic factors influence plant reproduction provides insight into how tropical communities will change with changing weather.

References

AIDE, T. M. 1987. Limbfalls: A major cause of sapling mortality for tropical forest plants. Biotropica 19: 284–285.

BURGER, W. C. 1983. Plants: Species accounts. *In* D. H. Janzen (Ed.). Costa Rican natural history, pp. 304-305. University of Chicago Press, Chicago, Illinois, USA.

BUSH, S. P. 2000. Clonal Reproduction Through Plant Fragments in *Poikilacanthus macranthus.* Monteverde: Ecology and Conservation of a Tropical Cloud Forest, pp. 88. Oxford University Press, New York.

BUSH, S. P., AND D. L. MULCAHY. 1999. The effects of regeneration by frag- mentation upon clonal diversity in the tropical forest shrub Poikilacanthus macranthus: Random amplified polymorphic DNA (RAPD) results. Mol. Ecol. 8: 865–870.

CLARK, K. L., R. O. LAWTON, P. R. BUTLER. 2000. The physical environment. *In* N. M. Nadkarni, and N. T. Wheelwright (Eds.). Monteverde: Ecology and conservation of a tropical cloud forest, pp. 15-38. Oxford University Press, New York, USA.

COOK, R. E. 1983. Clonal Plant Populations: A knowledge of clonal structure can affect the interpretation of data in a broad range of ecological and evolutionary studies. American Scientist, 71: 244-253.

DAWS, M. I., D. F. R. P. BURSLEM, L. M. CRABTREE, P. KIRKMAN, C. E. MULLINS, AND J. W. DALLING. 2002. Differences in seed germination responses may promote coexistence of four sympatric Piper species. Funct. Ecol. 16: 258–267.

FLEMING, T. H. 1983. Plants: Species accounts. *In* D. H. Janzen (Ed.). Costa Rican natural history, pp. 303-304. University of Chicago Press, Chicago, Illinois, USA.

GARTNER, B. L. 1989. Breakage and regrowth of *Piper* species in rain forest understory. Biotropica 21: 303–307.

GREIG, N. 1993a. Predispersal seed predation on five Piper species in tropical rainforest. Oecologia 93: 412–420.

GREIG, N. 1993b. Regeneration Mode in Neotropical *Piper*: Habitat and Species Comparisons. Ecology, 74: 2125-2135.

HABER, W. A. 2000a. Appendix 1: Vascular Plants of Monteverde. *In* N. M. Nadkarni, and N. T. Wheelwright (Eds.). Monteverde: Ecology and conservation of a tropical cloud forest, pp. 490. Oxford University Press, New York, USA.

HABER, W. A. 2000b. Plants and vegetation. *In* N. M. Nadkarni, and N. T. Wheelwright (Eds.). Monteverde: Ecology and conservation of a tropical cloud forest, pp. 39-94. Oxford University Press, New York, USA.

KINSMAN, S. 1990. Regeneration by Fragmentation in Tropical Montane Forest Shrubs. American Journal of Botany, 77: 1626-1633.

Kricher, J. 2011. Tropical Ecology, pp. 107. Princeton University Press, New Jersey, USA.

Lasso, E. 2011. Tropical Understory Piper Shrubs Maintain High Levels of Genotypic Diversity Despite Frequent Asexual Recruitment. Biotropica, 44: 35-43.

LaVal, R. K., and B. Rodríguez-H. 2002. Murciélagos de Costa Rica: Bats, pp. 28, 43, 87, 112, 159-160, 164, 166. INBio, Costa Rica.

López, J. E., and C. Vaughn. 2007. Food niche overlap among neotropical frugivorous bats in Costa Rica. Rev. Biol. Trop. 55: 301-313.

Sagers, C. L. 1993. Reproduction in neotropical shrubs: The occurrence and some mechanisms of asexuality. Ecology 74: 615–618.

Semple, K. 1974. Pollination in Piperaceae. Ann. MO. Bot. Gard. 61: 868– 871.

Silvertown, J. W., and J. L. Doust. 1993. Introduction to plant population biology. Blackwell Scientific Publications, Oxford, UK.

Wainwright, M. 2007. The mammals of Costa Rica, pp. 15, 85, 111-113, 150, 156-157. Zona Tropical, San Jose, Costa Rica.

Action Selection in Robotic Motion Learning

The University of Texas at Austin

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Abstract

Robot motion planning and control is essential for robots to navigate in the real world. Autonomous robots are expected to take actions on their own in order to actively explore an environment, rather than being fed by hand-tuned knowledge by a human. Stronger and Stone designed an algorithm, called ASAMI, which allows robots to learn their environment efficiently. However, it assumes access to some knowledge of the effect of the actions even though we may not have access to such information incertain domains.In this paper, I propose an extension on ASAMI which overcomes these drawbacks, and allows the robot to learn the actions as well as the environment simultaneously.

Introduction

There are two critical models for robot motion—the action model and the sensor model. The action model predicts the effect of an action, or formally, $A \rightarrow \Delta.S$, where A is the action space and S is the location space. The sensor model predicts the location given an observation, or formally, $O \rightarrow S$, where

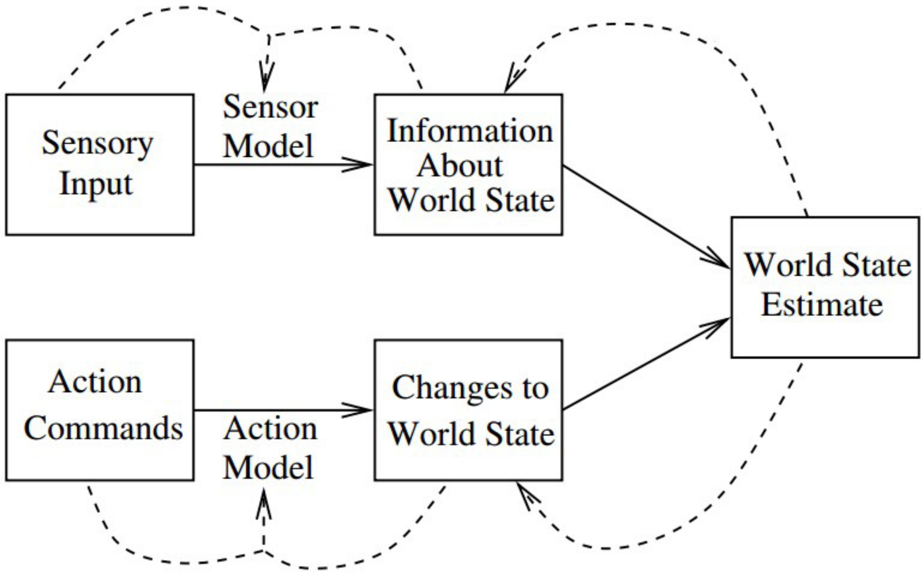
Figure 1. Robots play soccer. [2]

O is the observation space. Traditionally, these two models are fed to the robot by a human. The robot only needs to accomplish a higher-level goal, by planning and learning (Figure 1).

However, robots can learn the action model and the sensor model simultaneously without prior knowledge. One example of such learning is the ASAMI algorithm [10]. In the algorithm, there are two estimates of the current state of the robot—W_s, the state estimated by the sensor model, and W_a, the state estimated by the action model. They are both assumed to be polynomial functions, and the robot needs to estimate the parameters of each estimate. In a one-dimensional scenario, the robot is required to walk back and forth.

In one iteration, the action model is used to update the sensor model, and vice versa, leading to convergence. This idea is illustrated in Figure 2.

Figure 2. The robot can use redundant information to learn its action and sensor models, revised from Figure 2 in [10].



Analysis of ASAMI

In ASAMI, actions are selected randomly in the training. However, this can be biased according to the current belief. In this sense, the agent should be able to determine which action would lead to the most uncertain results and thus need more samples. It only knows the consistency of them, and has no knowledge about the correctness of the models. For example, states with a larger difference in the action model and the sensor model ($|Wa - Ws|$) should be considered inconsistent. For unobserved state, action pairs can be also assumed to be inconsistent.

The first author of [10], Dan Stronger, commented that "one possible reason the *Wa* is wrong after a certain action is that the action is just very noisy . . . This is a good reason to gather more data for that action . . . But another possible reason an action could be causing problems is because the action model function being fit, with the degrees of freedom that it has, just fits to a function that's not especially accurate for that action." This would be a problem in degree selection in the polynomial regression [12]. In this paper,

I give our action model proper degrees of freedom. So, if the action model is inconsistent, either there is too little data gathered, or the data gathered are too noisy.

Action selection is even necessary in some environments. The experiments in [10] assume that *we* know the effects of the actions (going forward, going backward, etc.). So to explore the environment, we make the robot walk forward and backward alternatively to explore the state space. However, the action's effects may be completely unknown. If the agent still chooses the actions to be uniformly random, then exploration would be inefficient.

For example, we consider a one-dimensional walk in which the world is in the range of [0, n]. The agent starts at 0, and wants to reach n. Let the range of velocity be [-2a, 2a], where positive velocities signify forward motion, and negative velocities signify backward motion. In every step the agent chooses a uniformly random action. Under these conditions, the expected absolute velocity of the walk is a. Assume the agent would "bump into" the boundary of 0 and stays there if it tries to go backward from position 0. The expected *moving forward* steps needed to take to reach position n from 0 is $^n/_a$. This creates a *random walk* [6] problem. The expected steps needed to take to reach distance n are $0(n^2)$. This implies that if an agent takes random actions in an unknown domain, it is likely that the agent would restrict itself within a small sub-domain.

Literature Review

In the perspective of model-adaptive agents [5], *action selection* is a critical problem because it involves accelerating the progress of an agent towards its goal—consistency between the action model and the transition model. This also relates to the problem of *learning from* experience, as the inconsistency is an essential piece of information that can be used for further decision-making. There is a two-dimensional version of ASAMI discussed in [11]. Because the action space is larger in higher dimensions, biasing on actions instead of random selection on actions becomes more essential.

Compared with this proposed method, some similar ideas are discussed in the developmental robotics literature. They call the inconsistency described above *error* [7], *surprise* [8] or *curiosity* [9]. This serves as a motivation to change the model. A metric can be used to describe the global inconsistency [7]. Then, a reinforcement learning framework can be used to plan to obtain the states with the least global inconsistency. The authors in [8] used logic rules as the model and let the robot figure out why there could be a surprise.In this paper, I assume that the surprise is caused by insufficient or noisy data. So the surprise, or inconsistency, of an action is simply caused by the data gathered at that action.

Additionally, there is an assumption in [10] that there is a mapping from action to the difference of state, i.e., $A \rightarrow \Delta.S$, where A is the action space and S is the state space. This is true in robot motion. So when an action is given, it is possible to learn the difference of the states. This is exactly how the task is designed in [4]. If this is not true, so that $S \quad A \rightarrow S$, is the best we can estimate, this would become more challenging.

We might know that a certain (s, a) is inconsistent and we want to gather more data on it. But our action model might not be well- learned, so the reward should be a compromise between the inconsistency of that (s, a) and the cost to reach it.

There are also other related works on learning the action model, but they make use of very different approaches. They assume that one model, usually the sensor model, is well-calibrated. The data are represented as either statistics [3] or instances [1]. These methods would be further analyzed and compared with our approach in Section 6.

Proposed Algorithm

In this section, I propose an algorithm, named Strong ASAMI, which makes the agent choose actions in a computationally cheap way. It retains the essentials of ASAMI; however, Strong ASAMI can be applied when there is no prior domain knowledge about the action model. The idea is that we divide the learning process into two phases. The agent learns the actions first and learns the state space later. In the first phase, it chooses the action with least confidence to learn. In the second phase, it uses the learned actions to explore the environment.

Some essential functions are presented in Algorithm 1. In initialization, a sample list is initialized for each action (Line 5). *A0* is the initial action model and its prediction for each action is pushed to the corresponding sample list. This is a useful initialization, as the variance of the sample list would represent the error of our initial model,

Algorithm 1 Strong ASAMI

1: **function** INITIALIZE *(range Of Actions)*
2:     *trials* ← 0
3:     *actions* ← discretized *rangeOf Actions*
4:     **for** *action* in *actions* **do**
5:         *samples*[*action*] ← {}   Initialize a sample set for each action
6:         *s* A_0*(action)*
7:         push *s* to *samples*[*action*]   add the prediction by the initial action model
8:     **end for**
9: **end function**
10:
11: **function** UPDATE(*action*, Δ*state*)
12:     add Δ*state* to *samples*[*action*]
13:     increase *trials*
14: **end function**
15:
16: **function** GETACTION
17:     **if** *trials* ≤ ACTION_LEARNING_TRIALS **then**
18:         *action* ← the action such that samples[*action*] has the largest variance
19:     **else**
20:     *action* ← appropriate action for state exploration
21:     **end if**
22: **end function**

when the first observed sample is added.

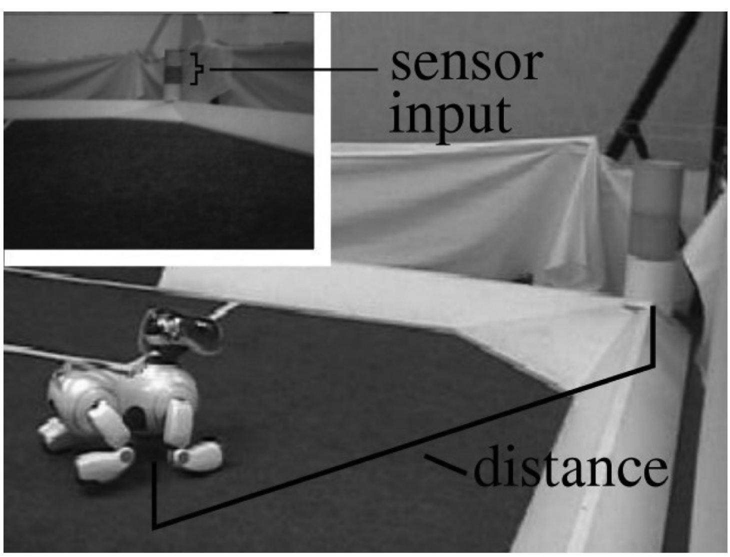
In each iteration, update (Line 11) is called to update the knowledgeof the action effects by adding new observations. When the robot needs to decide what action to take next, getAction (Line 16) is called. The action selection strategy in phase 2 (Line 20) always picks the action that has the largest variance in the observed samples. Then it keeps choosing actions to explore the environment. This is up to the agent to decide how to plan to traverse the state space. Consider a one-dimensional environment: it might want to keep trying actions with positive $\Delta state$. When it observes no state changes after executing such action, then it tries actions with negative $\Delta state$. With this, the robot should have the performance of walking forward and backward in the domain.

Experiments

The setup used in my experiment is the same setup used to evaluate ASAMI [10]. The plan for the experimental evaluation is detailed below. Firstly, the robot can walk back and forth in a one-dimensional path. There is a beacon placed at one end, and the robot is always facing towards the beacon. The only observation is the height of the beacon. The state is given by the distance to the beacon (Figure 3). The environment could be noisy—this is inherently true when doing experiment on real robots.

First, I test ASAMI in a toy domain. I only naively implemented the action model and the sensor model. Then, I made ASAMI and Strong ASAMI work on Aldebaran Nao robot. Action model and sensor model are both assumed to be cubic functions, and we

Figure 3. The observation is the height of the beacon in the experiment. The state is the distance to the beacon. Nao is used instead of Aibo shown in this figure. [10]



have four parameters to estimate for each model. The initial action model A_0 is defined to be a constant function, $A_0(x) = c$, where c is a small random number. This is used to train the state estimated by the action model w_a in the first 100 iterations.

The goal is to have w_s and w_a both converge and consistent with the true position, or state. It is possible that they are not numerically equal to the state, but they should have the same shape, that is, they could be an offset or scale of the true function.

Test in Simulator

The actions in the simulator are simply walking backward or forward. The robot can choose from velocity of [-1, 1]. The change of state is affected by the velocity. The sensor model computes the height of the beacon according to the current state. The result is in Figure 4. (See page 85.) There is no noise in the simulator so the results show that the learning on both models converge quickly. Estimates from both models have the same shape as the true states.

Test on Nao: First Attempt

The challenges of making ASAMI walk on Nao are that beacon height is too noisy, the height returned by the beacon detector could be noisy because the observed image can blur, and the real walking velocity can be different from what is set. The result is shown in Figure 5. (See page 85.)

The observation is retrieved and ASAMI is updated in each iteration. The beacon height shows that the robot walks forward and backward two times, and then kidnapped[1] from a further point to a closer point to the beacon in around 3,500 iteration.

Test on Nao: Second Attempt

I realized that making Nao observe while walking is not necessary, so I made the Nao observe while stationary. During the test, Nao will take an action, walk, and then stand still to observe the beacon. It keeps repeating this sequence. The result is shown in Figure 6. (See page 86.) The beacon height in the figure is the average of the observed beacon heights in the standing phase. Note that the x label in Figure 6 is different from that in Figure 5. In Figure 5, one iteration of ASAMI is exactly one frame on Nao. Here, one iteration of ASAMI takes many frames on Nao (one walking and one standing phase). This data is clearly more accurate because there is less noise in the observation.

Test on Nao: using Strong ASAMI

Strong ASAMI is applied in this experiment. The assumption is different from the previous ones—Nao does not have the knowledge of the actions. The results are in Figure 7. The beacon height shows that the robot tries different actions first (within 1,500 iterations, or frames) and then moves forward and backward to explore the state space.

Another intended goal is to show that convergence in Figure 7 (See page 86.) should be faster than that in previous experiments. Actually, the difference is not significant, at least for one-dimensional environment.

Discussion and Conclusion

The idea of action trials, which are the essential part of Strong ASAMI, is very similar to the idea of the multi-armed bandit problem [13]. In the multi-armed bandit problem, we choose one arm at each time and obtain a reward, with the objective to maximize the overall rewards. However, the goal of our problem should be to minimize the variance of all the actions. To solve this problem, I used an approach of choosing an action with the largest variance at each step. After such action, the variance of that action should decrease. The experiments have shown that this approach worked, even though there is room for improvement. For example, as the actions are not mutually independent, they are picked up from a continuous space; getting one sample of an action can help us know its neighborhood.

We assume the action space as a continuous space in the experiments. However, it is possible that learning each discrete action independently would have a better performance (same metric as [1]). The action model and the sensor model are both assumed to be polynomial functions in the experiments, but there are several constraints. First, degree selection should be determined, possibly using methods in [12]. However, the model may not be a small-dimensional polynomial, so there may be too many parameters to estimate. Second, the inherent limitation of function approximation method is that local updates could have global effects. This is especially harmful in a noisy environment.

In this paper, I show that Strong ASAMI has its power in the environment where action learning is necessary. This is just for one-dimensional environment, so future work can be extending this function to testing in multi-dimensional environments.

Endnote

1. Kidnapping means that while the robot is walking, you quickly put it to a different position. The robot would find its environment changes unpredictably, then it realizes its location changed.average of the observed beacon heights in the standing phase. Note that the x label in Figure 6 is different from that in Figure 5. In Figure 5, one iteration of ASAMI is exactly one frame on Nao. Here, one iteration of ASAMI takes many frames on Nao (one walking and one standing phase). This data is clearly more accurate because there is less noise in the observation.

Figure 4. The learning performance in the simulator.

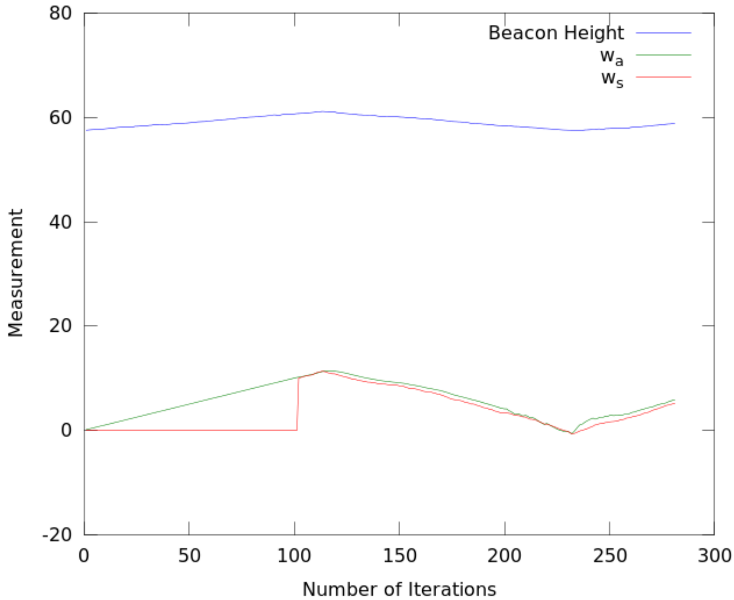


Figure 5. Testing of ASAMI on Nao during the class demo. The observation comes continuously, on average of 30 frames (iterations) per second. It is kidnapped at around 3,500th iteration.

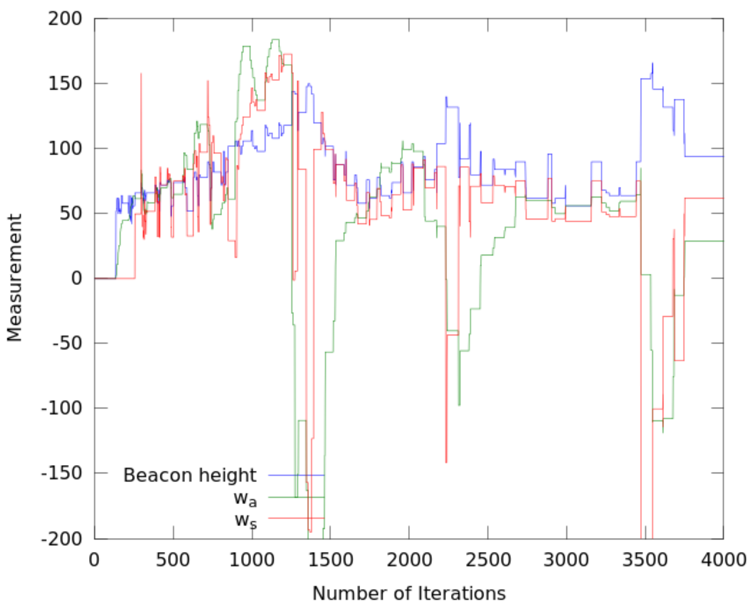


Figure 6. Testing of ASAMI on Nao. The observation comes only when it is in standing phase. There is less update in the observation, and less noise compared to Figure 5. One iteration of ASAMI corresponds to one update in the figure, which corresponding to many frames on Nao (I re-scaled the height of beacon, so that they can be plotted in a same magnitude).

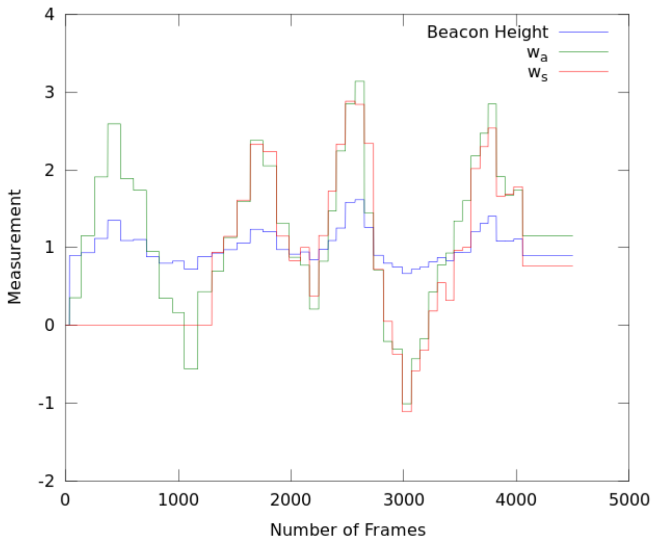
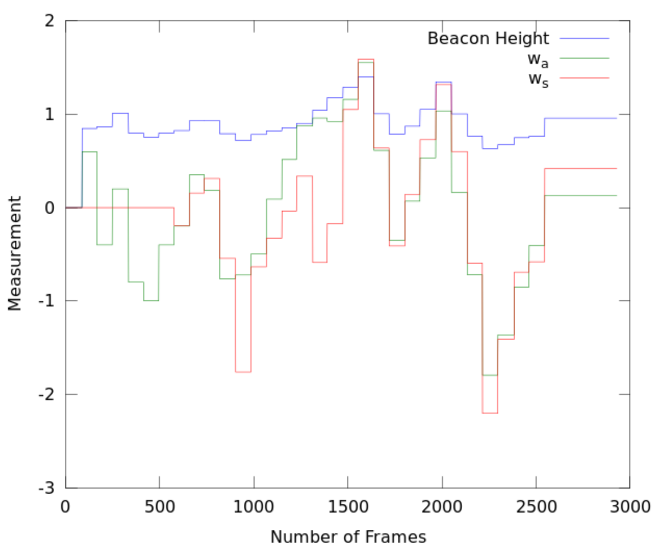


Figure 7. Testing of Strong ASAMI on Nao. The observation comes only when it is in standing phase—same as Figure 6. The robot tries to learn the action model first in the first 1,500 iterations, then continues to explore the state space (I re-scaled the height of beacon, so that they can be plotted in a same magnitude).



References

1. Mazda Ahmadi and Peter Stone. Instance-Based Action Models for Fast Action Planning. In Ubbo Visser, Fernando Ribeiro, Takeshi Ohashi, and Frank Dellaert, editors, *RoboCup-2007: Robot Soccer World Cup XI, volume 5001 of Lecture Notes in Artificial Intelligence,* pages 1–16. Springer Verlag, Berlin, 2008.

2. Samuel Barrett, Katie Genter, Yuchen He, Todd Hester, Piyush Khandelwal, Jacob Menashe, and Peter Stone. UT Austin Villa 2012: Standard Platform League World Champions. In Xiaoping Chen, Peter Stone, Luis Enrique Sucar, and Tijn Van der Zant, editors, *RoboCup-2012: Robot Soccer World Cup XVI,* Lecture Notes in Artificial Intelligence. Springer Verlag, Berlin, 2013.

3. Sonia Chernova, and Abstract Legged Robots. Learning and Using Models of Kicking Motions for Legged Robots.

4. Todd Hester and Peter Stone. Real Time Targeted Exploration in Large Domains. In *The Ninth International Conference on Development and Learning (ICDL),* August 2010.

5. Pattie Maes. Modeling Adaptive Autonomous Agents. *Artificial Life,* 1(1 2):135–162, 1993.

6. Rajeev Motwani. *Randomized Algorithms.* Cambridge University Press, 1995.

7. Pierre-Yves Oudeyer and Frédéric Kaplan. Discovering Communication. *Connection Science,* 18(2):189–206, 2006.

8. Nadeesha Ranasinghe and Wei-Min Shen. Surprise-Based Learning for Developmental Robotics. In *Learning and Adaptive Behaviors for Robotic Systems, 2008. LAB-RS'08. ECSIS Symposium,* on pages 65–70. IEEE, 2008.

9. Jürgen Schmidhuber. Developmental Robotics, Optimal Artificial Curiosity, Creativity, Music, and the Fine Arts. *Connection Science,* 18(2):173– 187, 2006.

10. Daniel Stronger and Peter Stone. Towards Autonomous Sensor and Actuator Model Induction on a Mobile Robot. *Connection Science,* 18(2):97– 119, 2006. Special Issue on Developmental Robotics.

11. Daniel Stronger and Peter Stone. Maximum Likelihood Estimation of Sensor and Action Model Functions on a Mobile Robot. In *IEEE International Conference on Robotics and Automation,* May 2008.

12. Daniel Stronger and Peter Stone. Polynomial regression with automated degree: A function approximator for autonomous agents. *International Journal on Artificial Intelligence Tools*, 17(1):159–174, February 2008.

13. Joannes Vermorel and Mehryar Mohri. Multi-Armed Bandit Algorithms and Empirical Evaluation. In *Machine Learning: ECML 2005,* pages 437–448. Springer, 2005.