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With special thanks and appreciation to the faculty mentors and volunteer reviewers.
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Submission Process
We are pleased to present volume XI of Explorations, the Journal of Undergraduate Research and Creative Activities for the State of North Carolina. For the fifth year, we have both scholarly articles and creative works. Again this year, I appreciate the assistance of Ned Irvine as Visual Arts Editor. His contributions and expertise are invaluable.

This year we include fifteen papers and one creative piece, selected from 24 submissions from students at twelve different public or private institutions in North Carolina, including the North Carolina School of Science and Math. Topics range from North Carolina history to engineering, from studies of the salt marsh to invasion of lionfish, from literary criticism to explorations of charitable giving. For the first time, we have a paper written in another language- an essay on the Jesuits written in French. Our creative piece is quite unique and combines book-building and illustration, creating a pop-up book.

It is useful each year to provide a bit of background about Explorations. I can hardly believe the journal has been a reality for eleven years! In 2005, the State of North Carolina Undergraduate Research and Creativity Symposium, affectionately known as SNCURCS (pronounced “Snickers”) was first held, and educators from all colleges, universities, community colleges, and high schools were invited to participate. Now in its 12th year, SNCURCS offers a venue for undergraduates to present their research and creative efforts. Explorations was the brainchild of the 2005 meeting, and we are thankful that Michael Bassman and East Carolina University organized and published the first three volumes. In 2008, the late George Barthalamus, former Director of Undergraduate Research at NCSU and the visionary behind our state-wide undergraduate research efforts, convinced me to move Explorations to UNCW in time to produce the 2009 volume, and we have now published eight volumes at UNCW. At UNCW we are fortunate to have a very successful Publishing Laboratory that developed the current look of Explorations, plus I have a great team of students who have done the layout for recent issues. I am indebted to Ms. Logan Prochaska, our assistant editor and layout designer and a member of the UNCW Honors College Media Board; she has done an amazing job with layout and keeping me on schedule. I also appreciate the copy editing of our CSURF graduate assistants and our assistant director of CSURF, Nathan Grove. I also thank Jennifer Horan, Peggy Styes and Morgan Alexander for day-to-day support in the Honors College office.

I am also very appreciative of the effort that the 41 ad hoc reviewers spent providing timely and thoughtful reviews of the submissions this summer. These are the folks who ensure the continued quality of Explorations. They offer very positive constructive feedback to the student authors.

This is the last year that I will serve as Editor-in-Chief of Explorations. I want to especially thank all the faculty reviewers and mentors over the years. You have given of your time and energy to support these students, a heartfelt thank you to you! And thanks to all the student authors. I have learned so much from reading your manuscripts- you are passionate and knowledgeable about your research and creative projects. I feel energized every summer reviewing your work! So in the spirit of the excitement that fresh approaches to research and discovery bring, we offer you volume XI of Explorations.

Katherine Bruce, PhD
Humanities
and
Fine Arts
Robert H. Jackson and the Nuremberg Trials: Justice and Diplomacy

Emma Caterinicchio
East Carolina University
Faculty Mentor: Wade Dudley
East Carolina University

ABSTRACT
After the bloodbath of the Second World War, the Allied Powers used trials instead of the usual treaty to set a new precedent for world peace and international law; these are widely known as the Nuremberg Trials. The trials not only broke ground in international law, but also served the diplomatic purpose of creating a post-war order between the victors and defeated, while acting as a possible deterrent to future aggressive war. The Chief prosecutor for the Americans, Justice Robert H. Jackson, is regarded as the key individual to consider when analyzing Nuremberg. He is often viewed in his role as a man of law; I argue that he was not only serving justice, but also acting as an agent of diplomacy. He represented the American legal and political philosophies abroad and took great efforts to assure the success of Nuremberg. By analyzing primary sources—documents from the trials, newspaper articles reporting on him, and articles published by Jackson after the trials—and secondary sources, I paint a picture of the man who both furthered the field of international law and represented the American program at Nuremberg.

In November 1945, twenty-two defendants, minus Martin Bormann, “who was prosecuted in absentia,” had to face the beginning of the trials that would determine their fates, which, for many of the former Nazis, meant execution.¹ These were known as the Nuremberg Trials. Although the American people initially favored the execution of the Nazis without a trial, the verdicts of the trials were generally received as positive progress and, perhaps, even too lenient.² The trials were an attempt by the Allies to create a post-war order, while preventing the issues that arose from the Treaty of Versailles and the Leipzig Trials after the First World War.³

The Nuremberg trials challenged the established boundaries between morality and legality, justice and victory, and dominance and punishment like never before. The trials at Nuremberg were key in shaping the increasingly globalized world following the horrors of the two World Wars. The trials were an important part for the Allied, especially American, program in making sure the path Germany had taken would never be taken again.⁴ The trials are often viewed in the context of morality: the victors of the war doing the world good by punishing the evil

³ Ibid., 5-6.
Adding more to his legacy than his time on the Supreme Court. Because the United States exerted the most control of all the Allies over the proceedings, and the legal and diplomatic implications of the Nuremberg Trials, Jackson is a key figure to analyze if one is to fully understand the role of the trials in creating a post-war order. The role of Robert H. Jackson as Chief American prosecutor in the Nuremberg trials should not be viewed simply as a lawyer fighting for justice, but also as a diplomat representing the values and interests of the American government after World War II.

Jackson is viewed in the fields of law and history as the key individual in the formation and execution of the Nuremberg Trials. He is met with both critique and praise, but, according to law professor John Q. Barrett, many would be “hard pressed to think who among his contemporaries in the United States government or private bar had his combination of stature and skill,” to carry out the job of Chief American prosecutor. Barrett acknowledges Jackson’s historical significance and ability to have played many roles, both judicial and diplomatic, at Nuremberg. Another professor of law, Dennis J. Hutchinson, also acknowledges the tendency of Jackson, and the trials themselves, to “[oscillate] from moment to moment between law and politics.” In contrast, Professor G. Edward White, a scholar in legal history, suggests that, “[Jackson] was a lawyer, not a hired man, and in suggesting the difference between the two he helped distinguish law from power or partisanship.” Although Jackson was a lawyer by trade and traditionally outfitted with the connotations of this title, the extent of his diplomacy is debated by scholars; most agree, however, that Jackson’s significance in Nuremberg cannot be ignored. As Dr.
William Maley of the Asia-Pacific College of Diplomacy, illustrates, “[Jackson] was not, in his design of the process, without flaw, but he outshone all other participants in the Trial in his sense of fundamental ethical importance of what was being attempted.”

Justice Robert H. Jackson was a man of the constitution. An associate justice of the Supreme Court, he viewed the trials as an event, “rather unique in the annals of law.” In its uniqueness, Nuremberg would be a challenge to Jackson’s own legal philosophies. The Nuremberg court itself would be prosecuting on grounds of ex post facto, or retroactive, law, a legal action that many Americans felt protected against by the United States Constitution, which Jackson, as a Supreme Court justice, was sworn to defend. Although international law was moving in the direction of illegalizing aggressive war—evident by the Kellogg Briand Pact of 1928 and the 1937 book by Soviet Russia’s Aron Trainin, The Defense of Peace and Criminal Law, which criticized the League of Nations for not criminalizing aggressive war and not creating an international court to convict this crime—the crimes the Nazis committed during World War II were not breaking any established international law. Even with regards to the growing evolution of international law, it has been established and generally accepted since the nineteenth century that bias is inevitable when a court of one nation is judging individuals of another nation.

Jackson himself once said that, “The world yields no respect for courts that are merely organized to convict.” It could be argued that the Nuremberg trials were, indeed, designed to convict the Nazis on the basis of diplomatic and moral motivation by the victors of a war; but Jackson went against his own initial doubts of the implication of ex post facto and the basis of the Nuremberg court in order to undertake the task of the main prosecutor. He defended the creation of the trials once he was sure to be an active participant. He believed that the trials, “fulfilled an immediate function which is both the most ancient and the most compelling purpose of all criminal justice, namely, substituting a reliable process of determining guilt for what was the most likely alternative—private, uncontrolled vengeance by those directly injured.” This “immediate function” was, in effect, the creation of a type of postwar power dynamic, necessary to fill the power vacuum in the fallen German nation.

In order to make the journey to Nuremberg, Jackson had to take a leave of absence from his position as associate Supreme Court justice, an action seen as an inconvenience by the other Supreme Court justices. The increased workload was not the only factor about Jackson’s absence that embittered the other justices, but also the legality of the Nuremberg trials themselves. Chief Justice Harlan Stone denounced the trials as a mere “high-grade lynching party.” Instead of consulting his legal brethren on accepting the position in the groundbreaking trials, Jackson consulted the man who deemed him the only man worthy of the job, President Truman. It is surmised that Jackson was special in his “matchless drive and leadership,” which led to him being the chosen representative.

Jackson’s excuse for not consulting his colleagues was met with the defense that “[he] knew that [Stone] would disapprove of [his] doing it. [He] didn’t have to ask [Stone] to know that.” Stone countered, believing that Jackson was involved in an act of catharsis, meaning that the trials were an act of therapy for the Allies, giving them a way to cope with

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22 Hockett, 264.
25 Hockett, 274.
27 Hockett, 278.
28 Ibid., 257.
the horrors of the Nazi crimes.\textsuperscript{30} Another theory for Jackson’s lack of consultation with his brethren, was his fear that his participation in the Nuremberg court would be seen as politically motivated.\textsuperscript{31} There is speculation that Jackson took the Nuremberg post, hoping that a closer relationship with Truman would lead to him being appointed Chief Justice, should Stone step down from his position (this was a likely possibility around this time).\textsuperscript{32} Jackson’s refusal to discuss his involvement with his fellow men of law can be seen as both a way for Jackson to deal with his going against established western legal principles and as a way to work closer with Truman. It should be noted that Jackson was a friend of both Roosevelt and Truman prior to the end of World War II; his selection could not have been purely because of legal merit, but also due to past ties.\textsuperscript{33}

When Jackson arrived in Nuremberg, he faced the challenge of assuming the role as a representative, or diplomat, of the United States’ program. Jackson, after the conclusion of the trials, illustrated that, in the Western world, men “of [his] profession,” that is, the men of law, were the most frequently chosen men to serve in executive and diplomatic roles.\textsuperscript{34} For a realist thinker, international laws themselves do not exist; the “lawyer” interpreting these laws is actually a diplomat seeking peace through the façade of justice, while the idealist believes ideas have inherent weight and consequence.\textsuperscript{35} Jackson’s actions at Nuremberg helped break ground in the field of international law, formulating ideas of consequence (such as making crimes against humanity illegal), but he had the mentality and assertiveness of a diplomat. In fact, Jackson was widely considered be the preferred candidate to succeed FDR in 1941, so his political and diplomatic potential was acknowledged.\textsuperscript{36} Jackson’s own agenda was not ignored when going to Nuremberg. Jackson had the intentions to “redefine the proper relations between individual citizens and the state in post-war America.”\textsuperscript{37} He would later accomplish this by promoting the Nuremberg conviction that held individuals accountable in wartime (the importance of which he clearly outlines in his statement made on August 12, 1945, shortly before the beginning of the trials).\textsuperscript{38}

Professor C. Arnold Anderson generalized that, “after war people want only to be done with hatred and carnage and have sympathy for their fallen foe,” but that, “diplomats... renew wartime bitterness.”\textsuperscript{39} For Jackson, quoted in a New York Times article before the start of the trials, it was vital that, “[t]here [would] be no censorship on what transpires in the courtroom and no part of the court proceedings [would] be secret. The trial of major European war criminals [was to] be a public trial.”\textsuperscript{40} Jackson calling the war criminals “European,” as opposed to “German” or “Nazi,” perpetuates the American view that the World Wars were waged by the Europeans; the Americans were being the saviors of the Allies and the deliverers of justice to the Nazis.

According to Gordon Dean, of Counsel for the United States, “The first challenge which Jackson faced was that of formulating a program, an American program, which he could take with him into negotiation with representation of the other Powers and urge its adoption.”\textsuperscript{41} As opposed to his usual role of defending the constitution and collaborating with his fellow men of law, Jackson was forced to create this American program, not without the input and support of the President and other American diplomats. He accomplished this and gave the proposal to the other Allied powers, who gave their critique.\textsuperscript{42} Jackson illustrated in his report on the

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International Conference on Military trials that, “What is [hard] for Americans to recognize is that trials which we regard as fair and just may be regarded in Continental countries as not only inadequate to protect society but also as inadequate to protect the accused individual. However, features of both systems were amalgamated to safeguard both the rights of the defendants and the interests of society.”\[43\] This shows an effort in Jackson to both defend the ideals of his country, but also make negotiations with the other representatives in order to ensure the success of the trials.

In a passionately written report to President Truman released by the White House on June 7, 1945, before the start of the trials, Jackson stated, “The American case is being prepared on the assumption that an inescapable responsibility rests upon this country to conduct an inquiry, preferably in association with others, but alone if necessary, into the culpability of those whom there is probable cause to accuse of atrocities and other crimes. We have many such men in our possession.”\[44\] In the same report, Jackson illustrates the various tasks he has done in order to prepare the trials, including collaborating with those collecting and processing the evidence, visiting Nuremberg and witnessing the interrogation of the defendants, preparing the cases the United States would prosecute, and working with the United Nations War Crimes Commission to appoint the United Kingdom representative in the joint prosecution.\[45\] Jackson too announced his views on the universality of the Nazi crimes:

We can save ourselves from those pitfalls if our test of what legally is crime gives recognition to those things which fundamentally outraged the conscience of the American people and brought them finally to the conviction that their own liberty and civilization could not persist in the same world with the Nazi power. Those acts which offended the conscience of our people were criminal by standards generally accepted in all civilized countries, and I believe that we may proceed to punish those responsible in full accord with both our own traditions of fairness and with standards of just conduct which have been internationally accepted. I think also that through these trials we should be able to establish that a process of retribution by law awaits those who in the future similarly attack civilization. Before stating these offenses in legal terms and concepts, let me recall what it was that affronted the sense of justice of our peoples.\[46\]

In his report addressed to the President (but published by the government for the public), Jackson stated that, “The legal position which the United States will maintain, being thus based on the common sense of justice, is relatively simple and non-technical. We must not permit it to be complicated or obscured by sterile legalisms developed in the age of imperialism to make war respectable.”\[47\] Jackson interpreted federal constitutional law; since his argument that common sense, not historically established ideologies, should be emphasized in the American program, he effectively stood against his own patterns of legal philosophies in order to defend and rationalize the United States partaking in retroactive law. In order to encourage the trials, as representing the American ideal that the trials, not a mass execution, were required to handle the Nazis, Jackson could not stick strictly to his traditional legal philosophies.

Other developments before the start of the trials showed Jackson asserting his dominance over the other Allies in order to push the American program. On August 3, 1945.

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43 Ibid.
45 Jackson, Trial of War Criminals, 1.
46 Ibid., 5.
it was reported that “the Big Three wanted ‘speedy agreement’ on the creation of an international crimes tribunal. . . Justice Jackson let it be known that he had served a polite ultimatum on his colleagues to expedite their deliberations lest the United States withdraw.”

Another New York Times article, published two days later, stated, “Apparently, the last obstacles to completion of the agreement were cleared up when Supreme Justice Robert H. Jackson, chief of the United States counsel on the Allied War Crimes Commission, went to Potsdam last week to press for decision from the Big Three. Precisely what Justice Jackson accomplished at Potsdam is not yet known.”

An article published just four days afterwards stated, “The [agreement of the four powers to criminalize aggressive war] sets precedents in international law and, in the words of United States Supreme Court Justice Robert H. Jackson, the American representative, ‘ought to make clear to the world that those who lead their nations into aggressive war face individual accountability for such acts.’

This shows Jackson’s heavy hand in, first, influencing the outcome of holding the trials, and, second, making the waging of an aggressive war a criminal act. Jackson’s assertiveness in dominating the Big Three is rather diplomatic in nature.

Jackson also asserted, “If we can cultivate in the world the idea that aggressive war making is the way to a prisoners’ dock rather than the way to honors . . . we will have accomplished something toward making peace more secure.”

This clearly shows Jackson’s motives in establishing a new precedent in international law and his hope that illegalizing aggressive war would lead to a new world order—fostered by American ideologies—that would be more peaceful than the blood bath of the early twentieth century.

Once the trials began, Jackson, in his now widely cited opening statement for the prosecution, fanned the flames of anger towards the Nazi defendants. This, naturally, is necessary for a prosecutor to do, but the guilt of the Nazis was already considered by Jackson to be a certainty and he knew of the publicity of the opening statement.

In his opening statement for the United States, Jackson seems to not only address the members of the Nuremberg court, but also citizens of the modern world, “You will have difficulty, as I have, to look into the faces of these defendants and believe that in this Twentieth Century human beings could inflict such sufferings as will be proved here on their own countrymen as well as upon their so-called ‘inferior’ enemies.”

Further along in the famed opening, Jackson, like a proper diplomat, gives the United States much of the credit in establishing the Charter of the International Military Tribunal (another name for the Nuremberg trials):

The Charter of this Tribunal evidences a faith that the law is not only to govern the conduct of little men, but that even rulers are, as Lord Chief Justice Coke put it to King James, “under God and the law.” The United States believed that the law long has afforded standards by which a judicial hearing could be conducted to make sure that we punish only the right men and for the right reasons. Following the instruction of the late President Roosevelt and the decision of the Yalta Conference, President Truman directed representatives of the United States to formulate a proposed International Agreement, which was submitted during the San Francisco Conference to Foreign Ministers of the United Kingdom, the Soviet Union, and the Provisional Government of France. With many modifications, that proposal has become the Charter of this Tribunal.

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53 Jackson, The Case Against the Nazi War Criminals, 34.

54 Jackson, The Case Against the Nazi War Criminals, 70.
Jackson’s agenda in criminalizing aggressive war is seen in the Charter Provision during the Judgment of the trials, as it is stated in the Judgment, although not read directly by Mr. Jackson, “War is essentially an evil thing. Its consequences are not confined to the belligerent states alone, but affect the whole world.” The criminalizing of aggressive war was met with uproar in the American military community. Although the Secretary of War determined that the Nuremberg trials were good, most military leaders were worried about the implications of criminalizing war and the effect that the prosecution of military professionals would have on the future of their profession. In a press conference to address these concerns, Jackson “angrily repeated his argument that the German military leaders were not being indicted or tried because of their mere membership in a ‘profession’ but for inhumane and monstrous outrages for conspiring to bring on an unjust war which had consumed many innocent lives.” The diplomacy of the Nuremberg trials was indirectly addressed in this back and forth, as the military men essentially had to learn the lesson that “the best way to avoid prosecution and the horrors of defeat was to win wars.” Caught in the middle was Army Chief of Staff Dwight David Eisenhower, who was an encourager of the trials as well as a military man. He said, “First, we don’t have a dictator, thank God, and second; I was in the field,” but his reasoning for the military man not to fear was weak and there was evidence that he himself contributed to part of the decision making in Nuremberg.

On December 6, 1946, less than two months after the conclusion of the trials, Jackson gave a speech before a special group at the National War College in Washington, D.C. where he attempted to address the concerns raised by military personnel. In this speech, Jackson attempted to comfort the concerned men by showing that Secretary of War Stimson pushed the idea of outlawing aggressive war, “It is unfortunate that the judgment has not yet been published in the United States because the recital of the judgment against these individuals really shows what they were up to.” Jackson is shown to be an avid defendant of the charge against aggressive war, representing not only his own personal agenda, but also that of the American government and Secretary of War. Here, again, Jackson transcended his legal boundaries and acted as a cathartic representative.

Using law in the place of pure diplomacies proved to be a controversial and unique way to create post-war order; the Americans were viewed, even by their own people, as coddling the Nazis. It was “without question [that] the accused got an infinitely better deal than anyone ever did before a Nazi tribunal, or indeed amidst the infernal conditions of Auschwitz and Treblinka where even the preference of legal forms was abandoned.” As to the goal of the Nuremberg trials to act as a deterrent against aggressive war, it is speculated that, “[the modern world has], so far, managed to avoid a Third World War. But the reasons for that have everything to do with the balance of terror, and nothing at all to do with the legal aspirations projected from Nuremberg.”

The trials have been traditionally ignored by many historians because they do not fit in the normal schema of postwar German affairs, representing a “peaceful” cooperation which contrasted the disunity and hostility brought about by the bipolarized Cold War. To ignore the trials would be to ignore their significance in changing the global outlook.

56 Bosch, 166-183.
57 Bosch, 169.
58 Ibid., 170.
61 Ibid., 6.
62 Bosch, 89.
63 Biddiss, 613.
64 Ibid., 612.
on war and the assertion of America being the world power following World War II. The trials were referenced heavily during the Korean and Vietnam Wars, calling the United States a hypocrite for waging the very same aggressive war against Asia that they had, just decades ago, passionately outlawed. The North Vietnamese even announced that American pilots would be tried as war criminals, justifying this by saying the pilots were criminals under the Nuremberg Charter.

Nuremberg effectively changed the view of war and international law by the newly globalized world civilization. Robert H. Jackson was simultaneously an effective prosecutor, changing the history of international law, and a passionate representative of the ideals and motives of his country. He went against his legal philosophies, received much criticism, and devotedly defended the American program of postwar trials. Working closely with two presidents and the American government, Jackson completed his task of prosecuting the Nazi criminals in a manner deemed fair by the Allies. He represents the battle between the ideology of justice and the power of diplomacy. Jackson was a man who enthusiastically questioned the application of international law and empowered the status of his country in these groundbreaking trials at Nuremberg.

65 Bosch, 164.
66 Ibid., 182-197.
67 Ibid., 185.
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La dualité de l’État et de l’Église: Des missions socioreligieuses, économiques et politiques des jésuites français en Nouvelle France dans les années 1630

The Duality of State and Church: The Socioreligious, Economic and Political Missions of the French Jesuits in 1630s New France

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ABSTRACT
Catholic missionaries played an important role in the French colonization of New France (Canada) in the early seventeenth century. Missionaries of the Society of Jesus, known as Jesuits, were involved in the religious, social, economic, and political aspects of France’s imperial pretensions in North America. These efforts were characterized by collaboration and coexistence with the Native Americans rather than conquest and domination. In this article, I undertake a critical analysis of the Jesuit Relations published between 1632 and 1635 in order to provide textual evidence regarding the Jesuits’ missions in New France, which were centralized on the socioreligious integration of the Native Americans, the economic relationships between the French and Amerindians, and the role of key commercial and political actors in the French colonial enterprise in Canada.


Les missions des Jésuites n’étaient donc pas que religieuses, mais aussi des missions


The French had a unique approach to colonization. Partly because they came to the New World in comparatively small numbers and partly because they made their fortunes in Canada by trading furs with native hunters, they had to come to terms with native cultures and interact extensively,… but it was an empire not of domination and subjection, but of multistranded commercial/diplomatic links between France and the different Indian nations of the Canadian hinterland…. The French were not inherently kinder empire builders than the English, but their

Les Français, principalement les Jésuites et les commerçants de la Compagnie de la Nouvelle France qui étaient envoyés en Nouvelle France sous un contrat royal, avaient formé des alliances avec beaucoup de tribus amérindiennes. Quelques-unes des tribus les plus importantes et alliées principales des Français étaient les Hurons, les Montagnais et les Algonquins. Les Montagnais habitaient à coté de Québec, l’établissement français le plus important à l’époque (1630s), sur le fleuve Saint Laurent, jusqu’à Trois Rivières. Au sud-ouest de Trois Rivières se trouvaient les Algonquins. Tous les deux, les Montagnais et les Algonquins, allaient surtout à Québec pour des raisons commerciales—pour participer au commerce de la fourrure—et politiques—pour résoudre les conflits avec d’autres tribus amérindiennes tels que les Iroquois. Ensuite, au sud-ouest des Algonquins se trouvaient les Hurons, la nation amérindienne qui deviendrait la plus importante pour les Français en Amérique du Nord. Finalement, au sud de la nation huronne était la confédération iroquoise, alliée avec les Pays-Bas. (Figure 1). Les Iroquois étaient l’ennemi principal des Montagnais, des Algonquins et des Hurons et à cause des alliances entre ces trois peuples, les Français sont devenus ennemis des Iroquois aussi.

Pour comprendre les motifs des Jésuites en Nouvelle France, on doit identifier qui étaient les Jésuites. Les Jésuites étaient des membres de la Compagnie de Jésus, une organisation religieuse fondée entre 1534 et 1540, quand elle a été approuvée par le Pape Paul III. Saint Ignace de Loyola a été le fondateur et le premier Supérieur général de la Compagnie (Traub and Mooney, 2015). La Compagnie de Jésus s’est développée rapidement en Europe dès la fin du 16ème siècle et au cours du 17ème
siècle. Elle a joué un rôle important pendant la Contre-Réforme catholique en Europe entre 1560 et 1648 et particulièrement en France. La Réforme protestante s'est répandue rapidement en France. De nombreux nobles et membres de la famille royale sont devenus protestants et l'Eglise catholique romaine avait peur que la monarchie française ne devienne protestante (Pollen, 1912).


La France, sur ordre du roi Henri IV, a commencé à envoyer des Jésuites en Nouvelle France en 1610. Les Jésuites ont été choisis à cause des missions réussies d'autres Jésuites, comme Antonio Crimina, le Père Nunez et Saint Peter Claver, en Asie, en Afrique et en Amérique du Sud, respectivement (Pollen, 1908). Les deux premiers Jésuites français, les Pères Pierre Biard et Ennemond Massé, sont arrivés en Nouvelle France le 12 juin 1611. Ils y ont été envoyés par le Roi pour aider les Récollets, des missionnaires catholiques français de l'ordre des Franciscains qui n'avaient ni suffisamment de fonds ni assez de missionnaires pour avoir du succès. En 1625, sans beaucoup de progrès accompli par les Récollets, deux autres Jésuites, les Pères Charles Lallement et Jean de Brébeuf, ont été envoyés en Nouvelle France par le Roi pour s'installer sur les rives du fleuve Saint-Laurent aux environs de Québec. Cependant, les missions des Jésuites en Nouvelle France ont été interrompues car la Nouvelle France s'est rendue à l'Angleterre entre 1629 et 1632. Quand la France a repris ses ambitions coloniales en Nouvelle France en 1632, les Jésuites sont aussi revenus et « [they were]
placed in sole charge of the spiritual interests of both the settlers and Indians » (Thwaites, 1959, vol. I, Introduction, 9). Le Père Paul Le Jeune (le supérieur) et le Père Anne de Noué sont arrivés en Nouvelle France le 5 juillet 1632.


Les missions socio-religieuses

Les Jésuites sont peut-être mieux connus pour leurs missions religieuses en Nouvelle France à cause des *Relations*. Toutefois, les ambitions des missions religieuses des Jésuites étaient encore plus vastes que celle de convertir les Amérindiens au Christianisme. Quand on pense aux missions religieuses, on remarque surtout la conversion d’une religion à une autre. Cependant, une conversion religieuse est plus qu’une transformation religieuse, c’est aussi un changement de mode de vie. Les Jésuites ont utilisé la conversion des Amérindiens au Christianisme pour convertir également les Amérindiens au mode de vie français et pour les intégrer dans la société française en Nouvelle France. De plus, les Jésuites ont soigneusement choisi les Amérindiens à convertir—particulièrement les enfants, les malades, et les chefs des tribus—pour assurer que leurs conversions aient l’impact le plus durable.

Les Jésuites ont été spécifiquement sélectionnés par la couronne française pour leurs missions en Nouvelle France. Quand les premiers Jésuites sont arrivés en Nouvelle France en 1625, ils n’étaient pas les seuls missionnaires français ; il y avait aussi d’autres missionnaires catholiques, notamment les Récollets. Mais, en 1632, le gouvernement français a accordé à la Compagnie de Jésus le droit exclusif de convertir les Amérindiens en Nouvelle France parce que les Récollets n’avaient pas eu beaucoup de succès à convertir les Amérindiens (Thwaites, 1959, vol. I, Introduction).

Comme tous les Jésuites, Le Jeune était bien éduqué et il était enseignant. De plus, il était professeur de rhétorique.¹ Donc, il a su l’importance et la signification—et la puissance—des *Relations des Jésuites* en tant que récits influents.

La société française et la mission

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Les conversions que les Jésuites en Nouvelle France ont faites n’étaient pas seulement des conversions religieuses, mais également des conversions sociales. La raison pour cela est qu’à cette époque, la religion était un élément central de l’état et du gouvernement en France et beaucoup d’autres pays en Europe comme l’Espagne et l’Angleterre. Donc, bien que les Jésuites aient voulu convertir les Amérindiens au Catholétisme, ils ont aussi voulu convertir les Amérindiens au mode de vie français, en d’autres termes, la Francisation des Amérindiens. (Wygant, 146).

En Nouvelle France, la religion était la fondation de la société française et les Jésuites étaient bien intégrés dans cette société. A cause de leurs missions, les Jésuites ont représenté l’image du Christianisme et un mode de vie français pour les Amérindiens. Quand un Amérindien était converti ou était en train d’être converti, les Jésuites lui disaient qu’il devait renoncer à toutes ses traditions et rituels amérindiens et qu’il devait accepter et pratiquer les traditions et les rituels chrétiens. A ce propos, Le Jeune déclare :


Donc, pour les Amérindiens, c’était à la fois une conversion religieuse et une conversion au mode de vie français. Les Jésuites ont vraiment apprécié les Amérindiens qui avaient renoncé à leur mode de vie sauvage—un mode de vie nomade et « barbare »—et ont adopté un mode de vie français—un mode vie « civilisé ». De plus, les Jésuites craignaient que les Amérindiens qu’ils avaient convertis ne se réassimilent dans la société amérindienne et abandonnent les coutumes françaises et chrétiennes, si possible.

Les Français ont vu les Amérindiens comme des « sauvages, » un mot que les Jésuites utilisaient souvent dans les Relations. Aussi, les Jésuites et les Français ont voulu civiliser les Amérindiens et les libérer de la pauvreté. Cette notion est claire dans les Relations. Le Jeune déclare que les Jésuites (et les Français, en général) voulaient civiliser les Amérindiens au Canada :

C’est à ce coup que la Nouvelle France se va ressentir des bénédictions de l’ancienne, & que l’équité triomphant de l’injustice, fera que ces contrées cesseront d’être ce qu’elles ont été depuis tant de siècles ; une forêt sans limites ; la demeure de la barbarie ; le pays de l’infidélité. Nous commençons à voir l’ouverture de quelques campagnes, par les défrichements qu’on fait en divers endroits ; Les familles qui passent chaque année, changent la barbarie des Sauvages en la courtoisie naturelle aux Français ; & le petit avancement que nous faisons par nos béguements, nous fait conjecturer que la foi bannira l’infidélité de son Empire. (Thwaites, 1959, vol. VII, 254).

Ce changement était très important pour les Français. Ils ont préféré que les Amérindiens soient des peuples sédentaires et agricoles car cet état faciliterait la conversion des Amérindiens.

Pour assurer la longévité du Christianisme, des conversions et de leurs missions en Nouvelle France, les Jésuites ont converti stratégiquement certains Amérindiens plus que d’autres. Au début de leurs missions, les Jésuites ont concentré leurs efforts, principalement, sur les enfants et les malades. On peut voir cette notion clairement dans les Relations. Premièrement, dans le Relation de 1633, Le Jeune souligne l’importance de convertir des enfants :

Pour le Séminaire,… si nous étions bastis, j’espérois que dans deux ans le P. Brebeuf nous envoiroit des enfants hurons ; on les pourrait instruire ici avec toute liberté, estans éloignés de leur parents. O le grand coup pour la gloire de Dieu, si cela se faisoit ! (Thwaites, 1959, vol. VI, 82).

Les Jésuites connaissaient la puissance des enfants ; ils voulaient convertir les enfants.
pour deux raisons. La première raison est que les Jésuites savaient que les enfants amérindiens étaient les plus vulnérables et donc, les enfants seraient les plus faciles à convertir. La deuxième raison, et la raison la plus importante, est que les Jésuites voulaient convertir les enfants afin de christianiser les générations futures. C’était une stratégie à long terme. En convertissant les enfants, les Jésuites savaient qu’ils pouvaient installer efficacement le Christianisme et assurer l’établissement du Christianisme en Nouvelle France.

Aussi, à cette époque, les maladies (comme la variole) qui attaquaient les Amérindiens à cause de leur contact avec les Européens, ont commencé à se propager rapidement de village en village. Les maladies ont provoqué un taux de mortalité élevé et ont tué beaucoup d’Amérindiens tout au long des années. Les Jésuites ont vu les maladies comme une occasion de convertir beaucoup d’Amérindiens. Ils ont réussi à convertir, ou à baptiser, de nombreux Amérindiens malades au cours des années, mais, pour la plupart, beaucoup de ces nouveaux chrétiens sont morts quelques jours après leurs baptêmes.

Dans la Relation de 1635, Le Jeune note que vingt-deux Amérindiens ont été baptisés cette année et il explique que les Jésuites voulaient seulement convertir les malades et les enfants:


Mais, les Jésuites ont eu, peut-être, une autre raison pour baptiser les malades : si le malade amérindien n’est pas mort, les Amérindiens penseraient que les Jésuites l’ont sauvé. De plus, les Jésuites étaient conscients de cette idée ; ils ont espéré être plus acceptés si les Amérindiens voyaient les Jésuites sauver leur compatriote malade. A ce propos, Le Jeune dit :


Les Jésuites utilisaient les malades comme une occasion pour influencer d’autres Amérindiens. Quand les Jésuites baptisaient un malade qui se remettait après le baptême, les Jésuites utilisaient cette occasion pour proclamer la puissance de Dieu et du Christianisme.

Les Missions Économiques

L’une des raisons principales pour la colonisation est l’économie. Une colonie est une occasion pour un pays de gagner des ressources naturelles et précieuses pour le commerce (Smith, 1904, Book IV, Chapter VII). Quand la France a débarqué en Nouvelle France au début du 17ème siècle sous Samuel de Champlain, chef colonial et cartographe, entre 1604 et 1609, les commerçants de fourrures français, ainsi que les pêcheurs et les explorateurs, ont développé de bonnes relations avec les Amérindiens le long de la côte atlantique vers le fleuve Saint-Laurent. (Thwaites, 1959, vol. I, Introdution, 3-4). Thwaites remarque que le commerçant précède toujours le prêtre (Thwaites, 1959, vol. I, Introduction, vii). Essentiellement,
le commerce était à la fondation d’une colonie. Au moment où les Jésuites et les colons étaient arrivés en Nouvelle France, les Français se sont implantés et ont commencé à étendre leur territoire et leurs efforts vers l’ouest le long du fleuve Saint-Laurent.

La France était très différente des autres pays européens dans la mesure où les colons ou les soldats français n’ont pas capturé ou tué les Amérindiens comme l’Espagne et l’Angleterre. Le Jeune exprime : « Si la mort de ces misérables apportait quelque profit à la traite des peaux, qu’on vient faire en ce pays ci, ce zèle de mort aurait quelque couleur ; mais leur vie et leur mort ne fait rien pour la traite » (Thwaites, 1959, vol. V, 46).

Les Jésuites faisaient partie intégrale du commerce entre les Français et les Amérindiens dans les premières années de la présence française parce qu’ils ont aidé à former des alliances entre les colons français et les Amérindiens. Si la France consistait en une entreprise en Nouvelle France, les Jésuites étaient les vendeurs. Les Jésuites ont développé des rapports avec des marchands et des commerçants de fourrures de la Compagnie de la Nouvelle France, qui étaient « involved in the colonial enterprise » (McShea, 2013), et étaient accordés la colonie de Nouvelle France et le territoire de la vallée de Saint-Laurent. Aussi, le gouvernement de France avait accordé à la Compagnie le monopole du commerce de la fourrure et, en échange, la Compagnie de la Nouvelle France amenait des colons en Nouvelle France.

Allan Greer décrit comment ces relations avec les commerçants et leurs implications dans le grand processus colonial ont formé une image des Jésuites qui était plus qu’une image religieuse, mais, en outre, une image coloniale et commerciale, en général :

Missionaries also followed the fur trade routes west to the land of the Hurons. From the beginning, then, the Jesuits appeared to native North Americans as part of a broader French presence. Accordingly, the relationships that developed between the Jesuits and the Iroquoians and Algonquians must always be seen as one aspect of a wider process of colonization. However much the Jesuits may have tried to shield converts from secular European influence, the whole missionary enterprise was affected by the larger pattern of relations between Indians and French.

(Greer, 2000, 9).

Le commerce entre les Amérindiens et les Français était complexe. Les Français voulaient faire des échanges commerciaux avec toutes les tribus amérindiennes, si possible, pour maximiser leurs profits économiques. Et donc, les Français, y compris les Jésuites, encourageaient les Amérindiens à venir les voir pour des raisons commerciales et sociales. Pourtant, certaines tribus amérindiennes—comme les Algonquins—voulaient le monopole du commerce avec les Français tout en excluant la participation des autres tribus.

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De plus, les concurrences entre les tribus amérindiennes, en général, à cette époque étaient plus que des concurrences territoriales et familiales ou des anciennes rivalités ; elles sont devenues de plus en plus des concurrences économiques. En 1632, à la même époque où Le Jeune faisait sa mission au Canada, Champlain a créé une carte importante qui démontre le rapport entre la cartographie et l’administration coloniale. Cette carte révèle les dimensions politiques et commerciales de la colonisation française et la répartition géographique des acteurs principaux dans les rapports politico-économiques franco-amérindiens : les Français à Québec à l’est, près de Trois Rivières, la nation algonquienne à l’ouest de Québec et la nation huronne au nord du Lac Saint-Louis (Figure 2). Parmi les nations amérindiennes, la nation huronne en particulier, les Jésuites étaient clairement perçus comme des émissaires français. À cause de cette constatation, les Jésuites étaient, pour la plupart, bien reçus par les Amérindiens parce que ceux-ci avaient déjà évalué les Français comme des fournisseurs de marchandises et de biens (Greer, 2000).

Au cours des premières années des missions des Jésuites en Nouvelle France, les Jésuites avaient deux objectifs principaux. Premièrement, ils ont essayé de convertir les Amérindiens—les Montagnais et les
Figure 2. Samuel de Champlain. « Carte de la Nouvelle France en 1632 ». http://jcb.lunaimaging.com/luna/servlet/detail/JCBMAPS~1~1~968~100580:Carte-de-la-Nouvelle-France,-augmen# Courtesy of the John Carter Brown Library at Brown University. Licensed under CC BY-NC-ND 4.0.
Algonquins principalement—qui allaient souvent à Québec et à Trois Rivières pour faire des échanges commerciaux. En plus, il y avait des Jésuites qui ont parcouru loin dans les terres amérindiennes pour faire du prosélytisme aux Hurons (Greer, 2000). Donc, les Jésuites se sont appuyés sur le commerce franco-amérindien pour pénétrer plus loin dans le territoire amérindien.

Le commerce de la fourrure a exigé de bonnes relations entre les Français et les Amérindiens. Les Jésuites, et les Français en général, ont réussi à développer des relations amicales avec les Amérindiens. Pour l’essentiel, ces relations augmentaient le commerce et fortifiaient la colonisation française. Et pour la longévité des Jésuites en Nouvelle France, ces relations et le commerce étaient impératifs. Mais, les relations entre les Jésuites et les marchands français de la Compagnie de la Nouvelle France étaient, peut-être, plus importantes parce que la Compagnie a soutenu financièrement et logistiquement une grande partie des missions des Jésuites.

Puisque la Société de Jésus n’était pas, en fait, une entreprise commerciale et les Jésuites n’étaient pas marchands, les Jésuites se sont appuyés sur les contributions de la Compagnie de la Nouvelle France et d’autres personnes puissantes en France qui profitent économiquement du commerce de la fourrure comme le Cardinal de Richelieu par exemple. Donc, les Jésuites ont voulu aider la Compagnie de la Nouvelle France; c’était dans l’intérêt des Jésuites que la Compagnie profite. Pour réaliser ce but, les Jésuites utilisaient les Relations pour promouvoir la Compagnie de la Nouvelle France.

Encore, ce n’était pas seulement la Compagnie de la Nouvelle France qui soutenait les Jésuites. Essentiellement, tous les gens qui achetaient les Relations ou investissaient dans la Compagnie de la Nouvelle France ont soutenu les missions des Jésuites en Nouvelle France. Dans une autre lettre qu’il a écrite au Révérend Père, le Provincial jésuite, Le Jeune glorifie la Compagnie, le roi de France, Monsieur le Cardinal et d’autres pour leur soutien et leurs contributions :

Et notre bon Roi, Monseigneur le Cardinal, Messieurs les Associés, Monsieur le Marquis de Gamache grand appui de notre Mission & quantité d’autres, par la faveur desquels le Sang du Fils de Dieu leur sera un jour appliqué, auront la gloire & le mérite d’avoir contribué à une si sainte œuvre. (Thwaites, 1959, vol. VI, 98-100).

Les Jésuites en Nouvelle France étaient vus comme une partie essentielle de l’effort colonial français qui a été impliqué dans le développement social et le commerce franco-amérindien. Ils utilisaient les Relations pour en tirer profit et obtenir le soutien de leurs missions et, dans l’ensemble, ils ont sûrement réussi. Les Jésuites étaient très impliqués dans le commerce en Nouvelle France et ils avaient des aspirations économiques eux-mêmes en tant que groupe.

Les Missions Politiques

Au début de la colonisation française en Nouvelle France, les Jésuites avaient joué un rôle important dans le domaine politique à cause de la constatation que la religion était la fondation de la société. À cause de cette idée, les Jésuites avaient beaucoup de puissance à cette époque-là. Les Jésuites étaient à la fois diplomates français et missionnaires religieux. Les rapports politiques entre les Jésuites et les Amérindiens étaient extrêmement importants et les manières particulières dont les Jésuites ont avancé une mission politique française—une mission concentrée sur les alliances franco-amérindiennes et l’expansion territoriale—en Nouvelle France ont joué un rôle central dans le développement de l’entreprise impériale française.

True explique que, quand les Jésuites sont arrivés en Nouvelle France en 1632, ils ont pris un rôle proéminent en raison de leur attention à la « politique des missions ». De plus, il dit que les Jésuites ont su l’importance de la collaboration avec le gouvernement et les intérêts commerciaux pour le succès de leurs missions. En outre, True affirme que la Compagnie de la Nouvelle France s’est alliée avec les Jésuites et leurs missions pour christianiser la Nouvelle France (True, 2015, Masters and Students, 33). La Compagnie savait l’importance, pour le succès colonial et économique, de christianiser les Amérindiens et elle a vu un moyen efficace pour atteindre cet objectif, les Jésuites.

Dans une lettre que Paul Le Jeune a écrite au Cardinal de Richelieu le 1er août 1635, on peut voir le rapport amical entre les Jésuites et Richelieu et comment les Jésuites étaient bien impliqués dans le domaine politique :

> Monseigneur vous estes le cœur et l’âme de cette compagnie et de toute la Nouvelle France vous pouvez non seulement donner la vie du corps à une infinité de pauvres artisans françois qui la vont mendier chez l’étranger faute de terre, mais vous pouvez encore donner la vie de l’âme à une infinité de peuples barbares qui meurent tous les jours dans l’esclavage de Satan, faute de prédicateurs de l’Evangile. Si votre Grandeur nous continue sa faveur et ces Messieurs leur bienveillance j’espère qu’aussitôt que nous saurons la langue que vous verrez et gouterez les fruits d’une nouvelle Eglise…. (Thwaites, 1959, vol. VII, 242-244).

Une grande partie du succès des Jésuites était donc dû à leur relation avec le Cardinal de Richelieu. Richelieu était, peut-être, la personne la plus influente pour les Jésuites et leurs missions en Nouvelle France parce qu’il était une figure centrale et dans l’Eglise et dans le gouvernement français ; il était le pont entre l’Eglise et le Roi pour les Jésuites. Sans leur rapport avec Richelieu et le gouvernement français, les missions des Jésuites en Nouvelle France et les Relations n’auraient pas été si vastes ou si réussies.

Les Jésuites utilisaient leurs relations avec les Amérindiens avec succès pour développer des alliances économiques et politiques de sorte que la France pouvait étendre sa portée coloniale sans commencer une guerre avec les Amérindiens pour revendiquer leur territoire. Ce sont les Jésuites qui ont contribué le plus à former et maintenir les alliances générales entre les Français et les Amérindiens. De plus, bien que la Compagnie de la Nouvelle France ait joué un rôle significatif dans la formation des associations économiques avec les Amérindiens, comme les Algonquins et les Hurons, les Jésuites étaient bien impliqués dans le commerce en Nouvelle France.

Un problème principal qui a limité la réussite des missions des Jésuites était que les Amérindiens étaient des peuples nomades, pour la plupart. Les Jésuites et les colons français préféraient que les Amérindiens deviennent sédentaires ; il était nécessaire que les Français comprennent le territoire d’Amérique du Nord et les alliances amérindiennes pour développer des stratégies coloniales. Aussi, les Français ont essayé de comprendre et de définir les territoires amérindiens sur leurs cartes. Sur une carte créée en 1641, on peut voir comment les Français ont défini certaines frontières des tribus amérindiennes en Nouvelle France (Figure 3). De cette manière, les cartographes français de cette époque, essayant de propager la notion que la France pouvait maîtriser les peuples amérindiens, ont imposé un ordre géo-politique sur les espaces cartographiques de la Nouvelle France.

Finalement, les Jésuites étaient bien impliqués dans les processus administratifs de leurs missions, et aussi, de la colonie. Dans leurs Relations, ils parlaient souvent des besoins de leurs missions. De plus, ils s’intéressaient aux exigences et à la situation actuelle de la vie en Nouvelle France (et de leurs missions, bien sûr). Ils mettaient l’accent sur la nourriture et d’autres provisions, la construction et la protection des bâtiments et les objectifs coloniaux. On peut les voir dans la même lettre que Le Jeune a écrite au Révérend Père Provincial de France :

Il y a quatre gros articles qui font la plus grande dépense de cette mission : les lards qu’on envoie, le beurre, les boissons et les farines…. Pour les blés, on a douté si la terre, où nous sommes, n’était point trop froide. Allons par ordre, et voyons la nature du sol : voici deux années que tout ce qui est du jardinage, qui ne lève que trop, a été mangé par la vermine…. Pour les arbres fruitiers, je ne sais ce qui en sera…. Pour le bled d’inde, il meurt bien l’an passé…. Primo, il se faut bastir pour nous loger, et les animaux et les bleds. Secundo, il faut semer maintenant ce qui est nécessaire, seulement pour le bestial…. Tertio, étant logés, tous nos gens s’appliqueront à la terre, à défricher et cultiver, pour avoir des bleds…. Voici une autre affaire : On parle de commencer de nouvelles habitations en divers endroits…. [C]e sera bien tout si nous faisons bien réussir le lieu où nous sommes…. (Thwaites, 1959, vol. VI, 72-78).

Les Jésuites n’étaient pas donc séparés des processus administratifs coloniaux. Ils étaient des participants actifs dans des objectifs coloniaux en Nouvelle France.

Conclusion

Les Jésuites ont joué un rôle essentiel dans les efforts de colonisation française en Nouvelle France dans les années 1632 à 1635. Ces objectifs de colonisation étaient caractérisés par des rapports sociaux, commerciaux et politiques avec des tribus amérindiennes, comme les Algonquins et les Hurons. Et les Jésuites étaient des figures importantes pour former et maintenir ces rapports. Les missions des Jésuites en Nouvelle France étaient plus que des missions religieuses ; elles étaient aussi des missions économiques.
et politiques. Une grande partie du succès des missions des Jésuites était attribuée aux *Relations des Jésuites*. Elles étaient des ouvrages de propagande qui avaient pour but de propager les objectifs religieux, commerciaux et politiques de la France au cours de son entreprise coloniale en Nouvelle France et elles étaient utilisées pour amasser des fonds et des soutiens logistiques pour les missions antérieures des Jésuites. Certes, les Jésuites ont subi de nombreuses épreuves au Canada à cause des topographies inconnues et difficiles à aborder, des événements climatiques violents, des maladies et des conflits avec des Amérindiens et leurs alliés européens. Toutefois, les Jésuites ont continué de poursuivre leurs objectifs en Nouvelle France avec un certain succès.
OUVRAGES CITÉS


“Grinding up the Seed Corn of the Confederacy”: The North Carolina Junior Reserves

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ABSTRACT

On February 17, 1864, the Confederate Congress placed white males, aged seventeen to eighteen, in the Reserves: “a robbing of the cradle” by President Jefferson Davis's standards. By June, North Carolina had organized eight battalions of Junior Reserves. Throughout 1864, the Reserves mostly did guard duty throughout the state, freeing other soldiers for field service. Although poorly equipped and not required to fight outside of North Carolina, the Junior Reserves unanimously volunteered to fight in Belfield, Virginia. For their service at Belfield, the North Carolina Legislature passed a vote of thanks to the Reserves. The Junior Reserves saw real action March 19-21, 1865 in the Battle of Bentonville in Johnston County. The battle took the lives of many soldiers, including some of the brave youths in the Junior Reserves. Major Walter Clark of the First Brigade Junior Reserves of Hoke’s Division described Bentonville as being “a good wood for skirmishing” and noted that “we had a regular Indian fight of it from behind trees.” Both primary and secondary source information on the North Carolina Junior Reserves are scarce. Most information comes from Clark’s Histories or The Walter Clark Papers, both of which were produced by Walter Clark. There are not many other accounts given, but William F. Beasley of the North Carolina Junior Reserves wrote to the Charlotte Observer that Clark’s claims were false and that he embellished his stories to glorify himself. Beasley wrote that he was particularly bothered by the fact that Clark claimed the title of the youngest commanding officer in the Confederacy, depriving Beasley of a title that was rightfully his. The purpose of this paper is to shed additional light on the Junior Reserves.
In a desperate attempt to regain ground near the end of the Civil War, the Confederate Congress passed a law on February 17, 1864 which placed males, aged seventeen to eighteen, in reserves. This resulted in the formation of the North Carolina Junior Reserves, a unique group of youthful soldiers who fought as a last resort for the Confederacy in North Carolina and Virginia, most notably in the Battle of Bentonville. Jefferson Davis, President of the Confederate States of America, described the formation of Junior Reserves as “a robbing of the cradle,” and North Carolina Governor Zebulon Vance referred to risking these young men in battle as “grinding up the seed corn of the Confederacy.”

It was to no one’s delight that seventeen-year-olds would be stripped from their homes to fight and die in the war, but leaders of the Confederacy believed that this time of desperation had left them with few alternatives. Lieutenant General Theophilus H. Holmes, an 1829 graduate of West Point, was appointed to command the North Carolina Reserves. Holmes felt that activating the Junior Reserves would “take but little from the agricultural interests” and that “little would be more than counterbalanced by the quiet and confidence incident to the security it will give to those that remain.” However, as the forlorn state of the Confederacy beckoned more males to military action, the agricultural burden fell to the hands of both white women and their female slaves.

Many parents of these youths did not believe that sending their children into battle would improve the war effort. In fact, many parents sent in formal requests for their sons to be alleviated of their duties in the Junior Reserves, most stating that the former needed the latter’s help on the farm. In total, there were 4,217 North Carolina Junior Reserves who fought in the Civil War. Thus out of 115,369 total North Carolina troops, the Junior Reserves constituted one-ninth of all North Carolina soldiers who fought in the war. The Junior Reserves’ experiences in the war resembled the exploits of the men with whom they served much more than those of the children and youths who remained at home. The experience of combat tends to strip the veneer of civilization from young warriors. These youths carried the horrors of war with them for the remainder of their life. Thirty-five years later, they and their children, strove to return North Carolina to as close to the “Old South” as possible with the establishment of de jure segregation. Thus, their experiences in war (and confusion existing about those experiences) are well worth consolidation and a scholarly examination.

The eight battalions of Junior Reserves were stationed across North Carolina, mostly to conduct picket and guard duty. On June 27, 1864, the 6th Battalion was ordered to Gaston, near the Virginia border, to protect a railroad bridge, while most others were sent to Wilmington and surrounding areas to guard Fort Fisher. At Wilmington, the last remaining Confederate port city, the North Carolina Junior Reserves did picket and guard duty on the beach to prevent the landing of enemies, escape of slaves, and communication amongst passing vessels. Employing the Junior Reserves in this capacity relieved the more experienced soldiers for field service.

On December 23-25, 1864, the Junior Reserves defended Fort Fisher when General B.F. Butler and Admiral D.D. Porter of the Union attacked it. During this skirmish, “quite a number” of Junior Reserves were killed or captured. The Junior Reserves’ conduct at Battle at Fort Fisher was not considered heroic in the eyes of many generals. However, it was the first time any of these

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4 Brown and Coffey, 42.
5 North Carolina Literary and Historical Association, Five Points in the Record of North Carolina in the Great War of 1861-5 (Goldsboro, NC: Nash Brothers Printers, 1904), 74.
7 Clark, 39, 45.
young men had seen military action. In some cases, their inexperience proved to be a hindrance. In a letter to General Lee, Brigadier-General Louis Herbert wrote:

The accessions of the Junior Reserves to my command cannot be said to have added to my strength. They are as yet totally ignorant of all military knowledge, and many are so weakly that they can perform but very little duty... Their officers are nearly as unexperienced and untaught as themselves.\(^8\)

In a letter to Secretary of War James Seddon, Major-General W.H.C. Whiting wrote that the Junior Reserves “would rather interfere than aid.” He went on to say that the youths were “prostrate with the diseases of children and too weak to bear arms” and “their officers, made by election, are entirely ignorant.”\(^9\) After their initial performance, it was apparent that the reality of the Reserves’ abilities to aid the Confederacy differed from the expectations of their leaders.

Disease constituted a major problem for the North Carolina Junior Reserves, particularly those from western and central counties; many of these individuals lost their lives to measles. Others fell ill to the chills and diarrhea, while Lieutenant Colonel Charles Broadfoot, commander of the 1st North Carolina Junior Reserves, cited lice and “the itch” were among some of the most significant ailments the young men experienced.\(^10\)

In addition to being fraught with disease, the Junior Reserves suffered from meager food rations. Colonel John Hinsdale stated that the rations at Kinston consisted of a mere half a pint of black sorghum soup, a pint of husky meal every other day, one-third pound of Nassau bacon, and occasionally, a few potatoes.\(^11\) Colonel Charles Broadfoot disclosed that the youths lacked shoes, underclothing, knapsacks, and cooking utensils. Moreover, the youth soldiers were “ragged and dirty.”\(^12\)

While the Junior Reserves were lacking in clothing and food, they were fairly well-armed. They had difficulties finding arms in the beginning, but they were eventually equipped with Enfield muskets (Figure 1), a British-made musket that was usually in ample supply despite scarcity of weapons in the south.\(^13\) Colonel Broadfoot wrote that the young men of the 1st Battalion later received the “better” guns that had been captured in Virginia and then given to the North Carolina Junior Reserves.\(^14\) On a somewhat comical note, Adolphus W. Mangum noted that some of the Junior Reserves “were exceedingly small and presented quite a grotesque picture as they lugged a huge musket around their

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10 Brown and Coffey, 97.
11 Clark, 53.
12 Brown and Coffey, 97.
14 Clark, 10.
On December 8 and 9 of 1864, several battalions of North Carolina Junior Reserves loaded a train to fight at Belfield, Virginia. By law, the Junior Reserves could not be required to fight outside of North Carolina, but the brave youths realized the critical state of the Confederacy and unanimously volunteered their service. Even before the young men arrived at the site, many had died. Captain David McKinne, of Company A, described the trip as “intensely cold,” and with the youths poorly clad and fed during this excursion. He recalled that it was so cold that several young men had to be taken off the train and held over a fire in order to preserve their lives. McKinne added that, because of the youths’ bravery and service at Belfield, the Legislature of North Carolina later extended a special vote of thanks to the Junior Reserves.\(^{16}\)

Writing about the Junior Reserves’ valor at the site, Colonel John Hinsdale stated, “The old guard of Napoleon on the retreat from Moscow never displayed more heroism and fortitude than did the boy soldiers—the young Guard of the Confederacy.”\(^{17}\) For their service in Belfield, the North Carolina Junior Reserves even received commendation from General Robert E. Lee. In a letter to Confederate Secretary of War James Seddon, General Lee wrote, “This exhibition of patriotism on the part of the Junior Reserves of North Carolina is highly gratifying and encouraging.”\(^{18}\)

After returning from Belfield, the Junior Reserves resumed guard duty in North Carolina, but they also saw action in several small battles across the state. While stationed near Smithfield, North Carolina, the 70th Regiment Junior Reserves were drawn up on three sides of a square to witness an execution. Several men from Zachary’s Georgia Regiment were to be shot for mutiny. The Confederates posted the Junior Reserves at this station as a precaution, as there were rumors of rescue of the men. Colonel Broadfoot reenacted the scene, telling of a detail firing their muskets at the miscreants. The executioners knew only half of the firearms were loaded, but they were not informed as to which; none would know who fired the fatal shots. Broadfoot ended his narrative with the sentence, “It was a painful scene.”\(^{19}\)

In the spring of 1865, the Junior Reserves fought in small battles such as the Battle of Wise’s Forks, near New Bern. On March 8, the young men, who had been on the skirmish line since early morning, moved considerably for a time, but at length one regiment broke and lay down, and the rest could not go forward. The next day, the Junior Reserves remained in the trenches along the creek. Considering their first day’s performance, the youth’s commanders kept them in the fortifications “waiting for the Yanks while the old soldiers… [did the] fighting.”\(^{20}\)

On March 16, General William J. Hardee’s division, including the North Carolina Junior Reserves, was repulsed in a “severe fight” at Averasboro and forced to yield the strategic crossroads formed by the junction of roads leading from Raleigh to Goldsboro. General Joseph E. Johnston, unsure of Sherman’s destination, ordered his army to concentrate at Smithfield, where he could threaten the flank of the invading army in the direction of either Raleigh or Goldsboro.\(^{21}\)

The Confederate soldiers knew the odds of winning the upcoming Battle of Bentonville stood not in their favor. On March 1, General Sherman reported 57,676 men. On March 17, Johnston had only 14,685. General Johnston’s numbers were then further reduced as Major General Ambrose Wright’s South Carolina Brigade was made to turn around at the North Carolina border because South Carolina Governor A.G. Magrath felt

\(^{15}\) Ibid., 757.
\(^{16}\) Ibid., 27-29.
\(^{17}\) Ibid., 43-44.
\(^{18}\) Brown and Coffey, 52.
\(^{19}\) Clark, 20.
they were needed for home defense. In addition to the lack of numbers, the men of General Hardee’s division ate nothing during the period from March 15 to March 18, and Hardee himself was weakened from Typhoid Fever throughout the month. 

In the days leading to the Battle of Bentonville, thousands tried to ensure their survival by purchasing repeating rifles for the upcoming skirmish. For forty-eight dollars, about four months pay, a soldier could arm himself with this new firearm. The rifle, which was new as a weapon of war, proved the major tactical weapon of the Civil War. It could fire a bullet with “man-killing accuracy” over eight hundred yards, much farther than the effective range of the smoothbore muskets which many of the Junior Reserves carried.

Just before dawn on March 18, a courier reached General Johnston at his headquarters in Smithfield. The dispatch he delivered was from Wade Hampton, who commanded Confederate cavalry in the region. Hampton was encamped about twelve miles south, near the village of Bentonville. He had just encountered a portion of the advancing Union army under General William T. Sherman. On the night of March 18, the Junior Reserves arrived at Bentonville and camped in the woods beyond the stream that runs through the village. Both armies experienced difficulty arriving at Bentonville, as the continued rainfall had turned the roads into rivers of mud.

On March 19, it was Hoke’s Division, which included the North Carolina Junior Reserves, that stood first on the ground. Their line was formed across the Goldsboro road, almost at right angles. General Braxton Bragg, who had been relieved of his command in 1863 after a devastating loss, was in charge of Hoke’s Division. The soldiers were placed on the Confederate left. The Confederate cavalry moved forward and reoccupied the position they held the previous evening. Under the protection of dismounted cavalry, Johnston made his dispositions. Hardee ran his line virtually parallel to the Goldsboro road, which created a sickle-shaped Confederate line.

General Bragg did not employ the Junior Reserves in the main Confederate assault on March 19, but Lieutenant Colonel Charles Broadfoot, of the 70th Regiment, looked on at the battlefield that bright Sunday morning and described the action:

> Several officers led the charge on horseback across an open field in full view, with colors flying and line of battle in such perfect order as to be able to distinguish the several field officers in proper place and followed by a battery which dashed at full gallop, wheeled, unlimbered and opened fire. It looked like a picture and at our distance was truly beautiful. But it was painful to see how close their battle flags were together, regiments being scarcely larger than companies, and [the] division not much larger than a regiment should be.

One of Slocum’s officers described his view of the same scene in a journal entry, “The Rebel regiments in front were in full view, stretching through the fields to the left as far as one could see, advancing rapidly, and firing as they came. It was a gallant sight. The onward sweep of the Rebel lines was like the waves of the ocean, resistless.”

The fighting continued into the night of March 19. Both armies on the battlefield toiled to strengthen their defenses. A member of the second South Carolina was walking the field that night when he came upon a freshly-dug grave of a mere fourteen-year-old boy who had been killed in the fighting that day. He later wrote, “The sight of it awakened sad feelings... I was myself only seventeen years of age, having volunteered at Charleston in 1864.” The teenager was
one of thousands who lost his life in battle that day. The total Confederate casualties at Bentonville for March 19 came to 2,462—over 15 percent of the men who arrived that day to fight. Of those Confederate casualties, 593 of them were under Hoke’s command. The Federals, who arrived with substantially more manpower, suffered 1,144 casualties the same day.\(^\text{32}\)

The next morning, the Union forces drove Hoke’s Division back, and the latter thus organized a new battle line facing nearly due east (the day before, they had faced southwest.) The Confederate division readily fortified the new line with log breastworks, hastily constructed, secured with earth dug up with bayonets, tin pans, and a few shovels. The skirmish line of each brigade stood about two hundred yards in front of the breastworks.\(^\text{33}\) The fighting on March 20, although relatively minor in nature, did involve a fiery contest between Howard and Hoke that afternoon. Between noon and dusk, the Union army repeatedly attacked Hoke’s division. The North Carolina Junior Reserves held an especially important position on this line. In General Hoke’s words, the Junior Reserves “repulsed every charge that was made upon them with very meagre and rapidly thrown up breastworks.”\(^\text{34}\)

Major Walter Clark was the seventeen-year-old commander of the brigade’s skirmish line, which twice turned back the enemy that day.\(^\text{34}\) Clark described the battleground at Bentonville (Figure 2) as “a good wood for skirmishing with little or no undergrowth” and wrote, “we had a regular Indian fight of it from behind the trees.”\(^\text{35}\) Under Clark’s command that day, the North Carolina Junior Reserves held their position as Sherman’s army repeatedly charged. The Federals sometimes drove the skirmishers in to their left and right, but the Confederate brigade held their ground for the entirety of the day.\(^\text{36}\) The defensive remained in the trenches all day, as Johnston hoped to induce Sherman to attack. Sherman, however, had no intention to bring on a general engagement until he opened communication with Generals Schofield and Terry at Goldsboro. He only pushed the skirmish lines forward to evaluate the Confederate positions, but he warned the corps commanders against committing their forces to an all-out battle.\(^\text{37}\)

The evening of March 20, a dense rain set in that lasted until the morning. The Confederate troops remained awake in their trenches throughout the night. Sherman would have rather avoided general battle, but since Johnston seemed to insist upon it, the

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32 Broadwater, 110.
33 Clark, 21.
34 Barrett, 337.
36 Clark, 21.
37 Luvaas, 351.
Union general felt it was necessary to accommodate him. Thus, the fighting resumed the morning of March 21.38 The Union right and center maintained continual pressure against the Confederate lines.38 When the fighting concluded, soldiers from both armies endured another miserable, rainy night. The tired and hungry men huddled together in their trenches and makeshift shelters, exposed to a downpour that deprived them of the ability to even make a campfire. Upon learning that night that General Schofield had arrived at Goldsboro, Johnston ordered an immediate retreat; and, by 2:00 in the morning, Johnston’s forces evacuated all the wounded that were able to be moved. The Confederates then abandoned their trenches and headed towards Smithfield. The Union army only followed Johnston for a few miles past Mill Creek, then turned back. They buried their dead and wounded, then camped near Goldsboro, where they obtained much-needed clothing and supplies.39

Bentonville produced 4,252 casualties for both armies combined. The Union army suffered 1,646 casualties, less than 3 percent of its available force. The Confederate army suffered 2,606 casualties, approximately 15 percent of the total engaged.40 The Junior Reserves lost forty-one of their own.41 By late-war standards, the Battle of Bentonville was hardly considered a skirmish. However, it is still the largest and bloodiest battle ever fought on North Carolina’s soil and the one where the Junior Reserves played the most significant role.42 Before the war concluded, one-half of major generals and one-fourth of brigadiers from North Carolina were killed in the Battle of Bentonville or died of wounds obtained during the battle.43

Bentonville constituted a key battle, but given its timing at the conclusion of the war effort, it is often neglected.44 Many do consider it to be the last important battle of the war.45 But had Bentonville occurred earlier, it may have been considered as one of the major struggles of the entire conflict. On the one hand, with only about four thousand casualties in three days, Bentonville did not produce the bloodshed necessary to astound the public.46 On the other hand, it marked the climax of the North Carolina Junior Reserves’ service. The courage of the Junior Reserves at Bentonville elicited high praise from their divisional commander, General Hoke. About their service, he said:

At Bentonville they held a very important part of the battle field in opposition to Sherman’s old and tried soldiers and repulsed every charge that was made upon them with very meager and rapidly thrown-up breastworks. Their conduct in camp, on the march, and on the battlefield was everything that could be expected from them, and I am free to say, was equal to that of the old soldiers who had passed through four years of war.47

The North Carolina Junior Reserves were praised for their brave service in various forms for years to come. An article from Confederate Veteran magazine said, about the Junior Reserves, “They were fearless and deserve as much credit as any soldier in the service. They never knew when to stop fighting.”48 Elizabeth McPherson, granddaughter of Theophilus H. Holmes, wrote a poem dedicated to the North Carolina Junior Reserves. It reads:

O, Sherman has come from Colombia,
He has foraged his way, mile by mile,
He has pillaged, and plundered, and ravaged,
He’s been king of the road, all the while;
But at Bentonville, Johnston stands in the way,
And Sherman must fight on the Sabbath Day.

O South, though you’re war-scarred and weary,
Exult o’er this radiant band,
Of your youngest, your not-yet-grown soldiers,
How proudly and firmly they stand.
Note their buoyant tread as they march along.
Listen, they’re singing an old Southern song.

In all youth’s power and glory,
With a sternness they’ve borrowed from men
They charge Sherman’s seasoned veterans,
They fight like wild furies and then—
Those childish faces, upturned and stark,
Can we leave them there in the growing dark?

For three days the battle rages,
Odds against us five to one,
Then slowly, and very sadly,
Each man shoulders his gun.
His name will be seen on the pages of fame,
But boyhood gets lost in war’s little game.

Hoke’s Division, Junior Reserves, Boys’ Brigade,
Call them what you will;
Just the mention of their names
Will always give the world a thrill.
To-day we carve those names in stone,
They wrote them in blood in the days long gone.

The bravery and sacrifice of the North Carolina Junior Reserves, though sometimes neglected, has not been forgotten. The youths “emerged with a reputation for bravery established for all time…” After Lee’s surrender at Appomattox Courthouse, the young men arrived in Randolph County and were paid $1.25 in silver. They then returned to their homes; the Junior Reserves were relieved of duty forever. At this time, Robert F. Hoke gave a speech to the soldiers of his Division, where he said:

My comrades, your indomitable courage,
your heroic fortitude, your patience under suffering have surrounded these with a halo which future years cannot dim. History will bear witness to your valor and succeeding generations will point with admiration to your grand struggle for constitutional freedom.

Soldiers, your past is full glory. Treasure it in your hearts. Remember each gory battle field, each day of victory, each bleeding comrade. Think then of your future... You have yielded to overwhelming forces, not to superior valor; you are paroled prisoners; not slaves; the love of liberty which led you in the contest still burns as brightly in your hearts as ever, cherish it, nourish it, associate it with the history of the past. Transmit to your children, teach them that the proudest day in all your proud career was on which you enlisted as a Southern soldier, entering that holy brotherhood whose ties are now sealed in the blood of your compatriots, who have fallen and whose history is covered with brilliant records….

It is no question that the North Carolina Junior Reserves have gone down in history as brave and gallant soldiers. When Charles W. Broadfoot later wrote about his experience with the Junior Reserves, he said, “We suffered, we fought, we failed, it has pleased some to call us rebels because we had done our duty, but history will record the names of the gallant, bright-faced boys of the North Carolina Junior Reserves on that page where only those of heroes are written.”

History has, in fact, recorded the names of these brave youths. However, information on the North Carolina Junior Reserves is not as abundant as that of many other Civil War topics. Most of the secondary source information that includes the Junior Reserves derives from one or both of two primary sources: Walter Clark’s Histories of the Several Regiments and Battalions of the Great War 1861-1865 and The Papers of Walter Clark. Clark was a soldier of the 71st Regiment and was elected Major of the 5th Battalion Junior Reserves. He asked for and received testimonies from various leaders of each regiment and compiled them for his Histories. A graduate of the University of North Carolina, Clark later became one of North Carolina’s most prominent attorneys as well as the Chief Justice of the North Carolina Supreme Court.

49 Ibid.
50 Brown and Coffey, 50.
51 Clark, 32-34.
52 Ibid., 22-23.
53 Clark, Brooks, Lefler, 52-53.
Although Clark was the only member of the Junior Reserves to publish primary material on the organization, one soldier, William Fessenden Beasley, wrote to a newspaper regarding Clark’s publication; the title of Beasley’s article: “History was Perverted: Justice Clark Betrayed Trust.” Beasley first argued that the man who “risks his life, voluntarily, for the defense of the state, or by its command, is unquestionably entitled to have his record fully protected….” He contended that Clark, an “exalted” Justice, “did not hesitate to use the money and good name of his State to edit, publish, and issue as history, falsehoods of the rankest character that might magnify his own importance.”

Beasley seemed especially concerned that Justice Clark “attempted to create… a false record for himself and to rob another officer of his rank.” He claimed that Clark “changed the sketches” of the Regiments of Junior Reserves and “had one purpose- to magnify his own importance by assigning himself a rank he did not hold and duties he did not perform.” Beasley acknowledged the severity of his accusations, but he also claimed to have written evidence “to prove every statement” he made.

Beasley stated his purpose as showing that Clark’s claims attempted “to rob [him] of the record [he] won and enjoyed until the State of North Carolina, through this high judicial officer, issued its unreliable history….” The author of this article supported his claims with written letters of support from Graham Daves, Lieutenant Colonel Charles W. Broadfoot, and N. A. Gregory. Beasley also found it important to note that, if Walter Clark “was lieutenant colonel of the Seventieth North Carolina Troops, he was the youngest officer of that rank in the Confederate army, but if he was not, then the writer is entitled to that honorable distinction.”

Regardless of whether or not Clark accurately depicted his rank and duties, there is no uncertainty that the unique organization of the North Carolina Junior Reserves was comprised of gallant young men who served their cause with pride. The Confederacy was far too despondent at the time the Junior Reserves were created to have made a recovery, but the youths who served did so with valor, and many gave the ultimate sacrifice for their cause. The “seed corn of the Confederacy” surely earned a place for their names on “that page where only those of heroes are written.”

In this paper, I have described the unique organization of the North Carolina Junior Reserves and their legacy as young warriors for the Confederacy. There is much that could be further considered regarding the Junior Reserves. Follow-up research could consider the long term economic factors in the decision to employ 17 to 18-year-olds with no military training or experience and the economic impact of losing so many young men from their generation.

Perhaps the post-war lives of individual survivors could be studied to determine whether or not their experiences as youths in combat shaped a certain path for the survivors. It could be worth consideration to contemplate the societal burden of a generation of men who were maimed physically and mentally by experiencing combat at a young age. One may also consider the place of these individuals in the rebuilding of the “New South” in the reconstruction era.

Information of the North Carolina Junior Reserves is neither abundant nor readily available. In fact, most of the existing information is used in this paper. Being a minute part of a complex period of history and being an organization formed as a last effort for the losing side are likely reasons that so few histories are written on the topic. Conceivably if such an organization had been formed for the Union Army, more records would be available, especially pensions, and more histories would have been written about the victorious regiment. Even in printed words, it seems, to the victors go the spoils.

54 William F. Beasley, “History was Perverted: Justice Clark Betrayed Trust,” Charlotte Observer, June 23, 1904.
55 Ibid.
56 Ibid.
57 Clark, 2 and 23.
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“The Orange and Navel”: Transgenerational Transmission of Trauma in Hanan al-Shaykh’s *The Story of Zahra*

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The *Story of Zahra*, a novel written by Hanan al-Shaykh, follows Zahra, a young woman growing up in Lebanon before and during the Civil War of 1975. Zahra experiences traumas throughout her life at the hands of her family members, lovers, country, and the civil war that tears it apart. Throughout the novel and seemingly as a result of these traumas, Zahra is often confined to her bed and even hospitalized multiple times, due to unspecified mental illness. Zahra’s relationship with her mother is a central aspect of the novel that is directly connected to the traumas she experiences. A strong and almost seemingly involuntary connection between her and her mother is established early on in the novel, and she consistently explains how the strengthening of this connection is fueled and almost forced by her mother.

Many readers and scholars commonly perceive Zahra as a one-dimensional, passive victim, rather than a victim of trauma actively responding to and coping with the compounded past and present traumas impacting her daily life. Zahra is read as passive and/or mad, (Accad 1; Larson 15) and in some cases, even self-destructive (Accad 1), among other negative and distrustful perceptions that all point to seeing her as an unreliable narrator and protagonist. In her article, “Sexuality, War, and Literature in Lebanon,” Accad calls Zahra “masochistic” because of the sexual relationship she has with the Sniper (Accad 1). She talks of Zahra as if she has no agency at all, or as if her madness is what fuels all of her decision making, and thus, as readers we should not see Zahra as legitimate. In a similar vein, Charles Larson calls Zahra “directionless” (Larson 14) once again denying Zahra any agency in her decisions, and acting as if Zahra’s experience of trauma results in her having some sort of deficit. Often, seemingly unintentionally or without awareness of the possible harm and delegitimization it can cause to Zahra as a protagonist and al-Shaykh’s novel as a whole, authors paint Zahra in a very negative light. I believe this perception of Zahra leads to devaluing the significance of the real experience of Lebanese people and specifically women in the Civil War that Zahra’s fictional experience represents.

In this paper, I explored the effects of Zahra’s and her mother’s traumas and experiences using the theory of transgenerational transmission of trauma to reconsider published critical analyses of the novel. I describe several instances of what I believe to be problematic interpretations of Zahra, the narrator, as “unreliable” in *The Story of Zahra*.

In their article, “A New Look at Transgenerational Trauma Transmission: Second-Generation Latino Immigrant...
Youth,” psychologists Suzanne Degges-White and Ricardo M. Phipps explain, “In recent years, there has been growing recognition of the existence of what researchers have labeled vicarious or secondary trauma; this can be experienced by those who have significant, close relationships to the direct victims of trauma, such as therapists or family members. Additionally, when the effects of trauma extend to other generations in the same family beyond the generation of the person experiencing primary trauma, the phenomenon has been labeled transgenerational trauma or intergenerational trauma” (Degges-White & Phipps 175). In addition, research has found that the transgenerational transmission of traits is seemingly more likely to come from the maternal side than the paternal side (Yahyabi, Zarghami & Marwah 91).

Zahra’s psychological state is a key focus of the novel and is addressed both directly and demonstratively through her narration, thus making it possible to apply the theory of transgenerational transmission of trauma to Zahra’s experience and explore the psychological effects the transmission has on Zahra. Based on the definition of transgenerational trauma, there are multiple instances in The Story of Zahra in which there is clear evidence of trauma transmission between Zahra and her mother.

For example, in the second chapter of the novel, the text presents a moment in which Zahra appears to hold a memory as a result of her mother’s transmission of trauma when she, who has had two abortions herself, remembers her mother’s abortion:

Ahmad was seven years older than me. Between us there had been a set of twins, girl and boy, who lived but briefly in a porcelain soup dish after my mother aborted them. Why did she let those bodies no bigger than a finger swim in a soup dish while she lay sprawled on the bed? The official midwife, Izdihar, shook her head, feeling sorry or happy, I did not know which. There was no accounting for it. I remember the neighbors pouring into the bedroom to greet my mother, then peering into the soup dish where the tiny embryos swam and then exclaiming, ‘In the name of Allah, the All Merciful. Blessed be the Creator. Look, here is a fully developed creature.’ But one was more forthright and asked, ‘Why abortion after abortion?’ Another grew more outspoken still, and spat, swearing and shoving the dish aside: ‘I spit on the human being. Is this how we all are created—as minute as a fingernail becoming as huge as mules!’ My mother would lean on a neighbor to visit the bathroom. The she would return to bed, pale, yet, with happiness almost jumping from her glistening eyes. She didn’t want to have children by my father. (al-Shaykh 26)

Clearly, in this scene, Zahra is describing an event that happened before she was born, and thus, logically, readers could interpret Zahra as unreliable. While that is a logical interpretation, upon further analysis, I believe this particular scene does not present Zahra as an unreliable narrator to readers, but rather as a recipient of her mother’s trauma. As a result of transgenerational trauma transmission, Zahra vividly remembers her mother’s abortion and feels the visceral combination of shame and relief that her mother experienced due to aborting a child whose father physically and emotionally abuses her. It is possible that when Zahra says that she remembers, she is not necessarily speaking literally. Thus, this demonstrates that the trauma her mother experienced as a result of the abortion, along with the backlash that she received from her community after she had it, was passed on to Zahra, when her mother shared this experience with her. Additionally, the transmitted trauma from her mother is compounded by the trauma Zahra herself experiences at the hands of the same event and the same societal pressures. For example, while locked in the bathroom after she is married to Majed, her uncle’s friend who lives in Africa in exile, Zahra remembers the traumatic event of one of her own abortions and identifies how social pressures as a result of her abortion, which are the same social pressures her mother experiences, led her to marry Majed: “I wish to remain forever in this bathroom despite all the knocks on the door that still throb in my ears and the voice of the stranger who has entered my life because I was once spread out on the old doctor’s table —
as his nurse combed her hair and casually put on lipstick. Because of that I am here, in this stranger’s bathroom” (al-Shaykh 99). Zahra and her mother have each acted in ways that are deemed unacceptable in Lebanese society due to beliefs influenced by patriarchy and misogyny, and as a result of this, they both are largely traumatized by the backlash they receive in response to these acts.

al-Shaykh demonstrates how similarly Zahra and her mother are affected by this trauma through the use of repetitive images in the text. For example, the image of Zahra during her abortion in which she spread out on the doctor’s table mirrors the image of her mother after her abortion as she is sprawled on the bed. Both women respond to the trauma of the event with the same exhausted relief to be without a child they did not want because the father of that child used, abused, and failed them. al-Shaykh employs this technique of repetitive action or mirroring again when Zahra is thinking about her marriage to Majed and how she is going to get through it, saying, “I don’t need to forget that I am capable of keeping my feelings to myself, especially since marriage, after a while, becomes a sort of contract. That was what Malek used to say. That is what everybody says. All I need to do is keep my real self hidden” (al-Shaykh 107). Zahra mirrors her mother’s relationship history in some ways, as she marries a man from whom she is forced to hide her “real self,” and who she does not love, but has entered into a sort of contract with.

In other moments in the text, al-Shaykh similarly creates mirror images of Zahra and her mother, especially in their responses to trauma. For example, when Zahra is witnessing her father abusing her mother and accusing her of adultery, she says, “I wanted then to run to her, to pull her to me so we could again become like orange and navel, and began to cry and whimper with her.” Later in this scene,

Zahra says, “Seeing the blood covering her face, I tore at my hair and beat my chest, exactly as she would do herself” (al-Shaykh 15). Once again, the image of the orange and navel appears, reminding us of the umbilical, inseparable nature of the connection between Zahra and her mother, a connection that can only be severed by further trauma: “My mother and I shouted out together as if we were once again as close as the orange and navel, as we had been when we stood trembling behind the door, back in my earliest memories” (al-Shaykh 136).

The image of the orange and navel appears again toward the end of the novel right before Zahra’s death at the hands of the Sniper. Initially, Zahra thinks of killing herself after learning she is pregnant with the Sniper’s baby, and she thinks of her mother discovering her death, saying, “I wondered whether she would think of the past, and of my existence as an extension of her own since we had been inseparable, like orange and navel” (al-Shaykh 196). As the novel is coming to a close, al-Shaykh repeats the image of the orange and the navel and reestablishes the connection between Zahra and her mother, which has greatly diminished over time. This moment recalls Zahra’s trauma and the roots of her trauma. It is almost as if Zahra herself is acknowledging the occurrence of the transgenerational transmission of trauma that has occurred between her and her mother.

The image of the orange and navel and its being reminiscent of the connection of a mother and child through the umbilical cord is significant and further provides evidence of this sort of transmission of trauma model because the umbilical cord is how the mother transmits nutrients and life to her baby when it is in the womb. It is possible to imagine that the traumas that the mother experiences can also be passed through the umbilical cord or through the closeness and connection of mother and child, which is like “the orange and navel.” Considering the literal image of the orange and navel is also significant, as the navel of the orange can only be removed by way of force or inducing a sort of trauma upon the orange and navel. The seeds of that traumatized orange remain and produce another generation of oranges, which then
experience more trauma and pass that down to another generation of oranges.

Diya Abdo points out how instances throughout the novel “[suggest] that [Zahra’s] memory, indeed her consciousness has not entirely been her own” (Abdo 222). This suggestion can on one hand be an explanation for thinking of Zahra as an unreliable narrator, and on another hand this suggestion shows that Zahra’s memory and consciousness is in fact not entirely her own because she is a recipient of trauma from previous generations. For example, Mona Fayad suggests that “Zahra is able to find a voice through telling her own story and her mother’s, providing, instead of the reassuring voice of the radio announcer that denies the existence of the war, an account, not only of the Lebanese Civil War itself, but of the social systems that generate the violence of the war” (Fayad ) Zahra’s mother has experienced trauma of various forms and transmitted that trauma to Zahra, she has also, as a result of her own trauma, contributed to Zahra’s traumatization in many situations. It is clear that her mother has also received her own trauma from previous generations and is deeply affected by that throughout her entire life. For example, when Zahra returns from Africa for the first time, she sees her mother and describes her by saying, “I saw my mother’s round face, seeming about to explode, so full was it with suppressed anxieties” (al-Shaykh 102). Zahra’s mother suppresses all emotions, not only those resulting from her own life of perpetual trauma, but from Zahra’s as well. Not only does Zahra in many ways learn and mirror this behavior, she is also directly affected by her mother’s suppression of her emotions from the moment she is born because that results in the transmission of her mother’s trauma to her.

Abdo posits that in The Story of Zahra, Zahra attempts to “rewrite the national self” and create a new national identity by means of employing “…subversive sexual and psychological identities constructed within and against highly patriarchal communities…” (Abdo 217). Abdo further explains how the woman as nation trope often shows itself in Lebanese society and that the fate and success of the nation is largely based on the purity of its women and their success in embodying the right woman based on patriarchal standards. She says, “Thus in Lebanon…woman’s role was circumscribed. Her place became restricted to and indeed epitomized by the private, the domestic, the apolitical and idealized in ‘pure’ womanhood and motherhood” (Abdo 220). Imposing the identity of a nation upon the identities of the women of that nation is in itself an action that causes harm upon those women due to the oppressive ideology of patriarchy that shapes and fuels the constant reproduction of this trope. Trauma can be, and is, enacted by ideology. Thus, as ideology carries over, and is strengthened and further enforced, trauma is transmitted across generations through each generation’s introduction and subscription to that ideology.

Like Abdo, Marianne Marroum points out that Zahra’s uncle, Hashem, and husband, Majed, substitute Zahra for Lebanon, their homeland, and I think that while that is a product of the perpetuation of the patriarchal woman as nation trope, it also highlights the significance of the timelessness, and sometimes placelessness, of Zahra’s memories, and the legitimacy of memories of such a quality. Marroum argues that The Story of Zahra is a “literature of displacement, one that is neither bound by time nor place” (Marroum 511). Marroum’s evidence relies on examining Hashem and Majed’s experience of exile and deep homesickness for Lebanon. I would add that Zahra’s ability to remember the past of her ancestors, for example, her mother’s abortion, is also evidence of that.

When explaining that there are many forms of homesickness, Marroum references Roberta Rubenstein, who coined the term “sickness of home” (Marroum 495) to describe a type of homesickness. This term refers to the idea that one can be made sick by their home due to the negative impact of certain ideologies of their homeland, i.e., the imposition of patriarchal ideals on women in
various countries, and this sickness can affect an individual even after they have left their homeland. This sickness of home can be transmitted between person to person who share the same home, something that Zahra points out in her observation of Hashem and Majed, who live in exile from Lebanon in Africa (Marroum 504). It can be argued that Zahra also notices that she herself has this sickness of home, and that anyone within or without their home country could have this sickness.

This sickness of home, which is produced by war and oppressive ideologies, is plausibly transmitted across generations and across a nation or nations. Combining this idea of a sickness acquired from one’s home, or specifically in this novel, a sickness acquired amongst Lebanese people as a result of a warring Lebanon, and the concept of transgenerational transmission of trauma, I believe another mode of transmission of trauma that is exemplified in this novel is what I call transnational transmission of trauma. Zahra and her experiences of trauma present various examples of this transnational transmission of trauma throughout the novel.

The most blatant example is the fact that Zahra, by both the novel itself, and by particular characters in the novel, is traumatized by the imposition of the woman as nation trope upon her, which results in her uncle seeking a misguided and detrimental solace in her that escalates to sexual abuse, as he is dealing with the trauma of exile and leaving his homeland, Lebanon. (Abdo 221; Adams 203; Marroum 503) This does not excuse his actions, but certainly contributes to a more nuanced understanding of Uncle Hashem, who also appears to be a recipient of the transnational trauma experienced by so many in Lebanon, but specifically by his family members, at the hands of the civil war. Speaking of both Hashem and Majed’s attempts to impose ideas and dreams of their nation onto Zahra, Adams points out that “neither man is able to understand or help the troubled girl because each is too busy attempting to fashion her as his own idealized image of Lebanon. As a result, they may come to understand that they want different things from Zahra…but they fail to acknowledge Zahra as an individual with her own personal needs” (Adams 203). This failure to acknowledge Zahra does her real harm that she cannot undo; and is evidence of the trauma that she experiences at the hands of the women as nation trope and the dominant patriarchal ideology of Lebanon.

I believe that Hanan al-Shaykh appears to be a recipient of both transgenerational trauma and transnational trauma. Abdo points out that Hanan al-Shaykh had a complicated and estranged relationship with her mother, which is how one could describe Zahra’s relationship with her mother, and which may point to transgenerational trauma transmission between al-Shaykh and her mother. Speaking of her mother in her essay, “War and Writing,” al-Shaykh says, “My mother remains my strongest connection to Lebanon. She represents my country of origins, my past and my history. She’s my memory” (al-Shaykh, “War and Writing” 17). Perhaps al-Shaykh shares her mother’s memories of Lebanon in the same way that Zahra shares her own mother’s memories. Both al-Shaykh and Zahra live in their mothers’ memories and because of their mothers’ memories, both as a result of being recipients of their mother’s trauma, along with carrying on their mother’s creative attempts at resistance. al-Shaykh explains that she wrote about her mother’s story and the stories of “many Arab women who lived before World War II” in another one of her novels, It’s A Long Story, and says of her mother, “She always wanted her story to be told because she suffered a lot. And by doing so, I am revisiting my country of youth” (al-Shaykh, “War and Writing”17). al-Shaykh is writing her mother’s story to understand that story, but also to understand how that story has grown into her own story. Considering this, whether or not al-Shaykh is conscious of the theory of transgenerational trauma transmission, it appears that she understands and subscribes to the basic ideas that explain the theory.

Regardless of explicitly knowing of the trauma she has received from past
generations, al-Shaykh clearly uses storytelling, and specifically, the telling of Zahra’s story, in order to unpack her trauma and the trauma her mother and ancestors have experienced. Multiple authors also point out the fact that Hanan al-Shaykh herself primarily experienced the Lebanese Civil War in exile in London, where she wrote The Story of Zahra as the war was happening, rather than in Lebanon, her homeland. It appears al-Shaykh is remembering her own experience of both transgenerational and transnational transmission of trauma in her writing of The Story of Zahra and commenting on the fact that she herself has been infected with the sickness of home as a result of the civil war. Further, she may be commenting on the trauma that she has experienced at the hands of the dominant patriarchal ideology of Lebanese society that she is acknowledging in The Story of Zahra. In the novel, she shows both Zahra and her mother being traumatized and oppressed by this ideology, while also attempting to resist the dominant ideology and beliefs that are imposed upon them as Lebanese women.

al-Shaykh’s writing of The Story of Zahra itself is resistance to this oppression that she and other Lebanese women have faced at the hands of patriarchy.

In “War and Writing,” al-Shaykh also discusses the current younger generation in Lebanon, whose forms of resistance against patriarchy she seems to disagree with, saying, “Now when I go to Lebanon I see girls going topless at the beach, and they think that’s revolutionary. Needless to mention they’re as oppressed as before only they don’t know it” (al-Shaykh, “War and Writing” 15). She goes on to say, “In my generation, on the other hand, we were all fighting before the war against that. We fought our families and our traditions. We fought misogyny and machismo. The surprising thing is that today’s women in Lebanon are perhaps better educated and more informed than my generation, but they are very subdued” (al-Shaykh, “War and Writing” 15). Here al-Shaykh is acknowledging, if not intentionally, how the trauma of patriarchy and misogyny is passed down or perpetuated by the transmission of this trauma through generations of women, and through the passing down or perpetuation of dominant ideology. She is also acknowledging the power of ideology to enact harm upon those who are forced to subscribe to it and are the most affected by it. Further, al-Shaykh is demonstrating how attempts at resistance of patriarchal oppression, however different the methods are, are passed down or transmitted through generations.

Using the theory of transgenerational transmission of trauma to analyze further the interpretation of Zahra as unreliable serves to present Zahra in a new light, along with restoring the reader’s sense of trust in her as a narrator. She emerges as a reliable narrator who is remembering as a result of both the very real trauma she experienced and also the trauma passed down from her mother to her. Zahra experiences her own very real traumas due to various events in her life, but that trauma is influenced and further exacerbated by the trauma experienced by previous generations in Lebanon, including that enacted upon the entire nation of Lebanon at the hands of the war. The Story of Zahra also appears to serve as a way for Hanan al-Shaykh to remember and cope with her own transgenerational and/or transnational trauma that she and so many other women have experienced due to the war and their experiences of patriarchy and misogyny as Lebanese women.
REFERENCES


Creative Work: “M.Y.O.B. Rd”
Pop-Up Book

Artist: Courtney Hockett
Faculty Mentor: Brandon Sanderson
Affiliation: University of North Carolina Pembroke
Dimensions: 7”X6.5”X18”
Medium: Graphite, watercolor, digital, bookbinding

ARTIST STATEMENT: “M.Y.O.B. Rd”, or “Mind Your Own Business Road,” was created in 2015 as a two-part grant through the Pembroke Undergraduate Research and Creativity Center in which I was given the opportunity to research how to incorporate creative literacy within art using the process of paper engineering. Even though the illustrations found within “M.Y.O.B. Rd” appear to tell a colorful and whimsical story, the contents resemble that of the literary genre Grit Lit and include details and scenes that are true to my childhood. In order to demonstrate the advancement of my skills in the field of paper engineering, I designed a series of four separate illustrations with four different pop-up templates ranging in difficulty: stationary, v-fold, complex moving, and an original design. Once all the illustrations and templates were complete, I assembled the final product by hand using the technique of book binding. By incorporating the concept of creative literacy, I was able to create an original book that allows viewers/readers to experience a story through interactive, three-dimensional illustrations.
Shards of gravel bit my arms as I squinted past the cloud of dirt flying out from under the back tires of my cousin Lacey’s go-kart. As we turned the corner, I shifted gears and continued to follow close behind. Lacey was a few years older than me, so Granny always left her in charge when she had to leave to run errands. She was my Bonnie and I was her Clyde. If there was mischief to be made, Lacey and I were the ones to do it. So it came as no surprise when I saw the street sign ahead with the letters “M.Y.O.B.” reflecting in the afternoon sunlight – we only ever came to these parts for one thing, and that was to start trouble.

This was the first time since school let out that I had been allowed to drive. Earlier that year Granny had restricted my faux license after I accidently drove off track and lunged head first into the neighbors’ ditch, destroying their mailbox and freshly planted tulips. I didn’t mean to get distracted, it’s just that Chingy’s “Right Thurr” came on the portable radio and you can’t not dance to that song. So needless to say, my right to drive had been revoked for a while.

The road was lined with signs warning strangers to “Beware of Dog” along with threatening comments poorly written on two-by-fours; such as my favorite “Shoot First, Call 911 Later” nailed to an old oak tree. I loosened my grip on the wheel and let my foot barely touch the gas, following Lacey’s hand gestures as she motioned for when and when not to add pressure to the brakes. We coasted down the dirt path and eased our go-karts into a spot in the woods so that we could be unseen.

I crawled on top of the roll cage and searched for a vehicle to ensure that no one was home. Lacey crept over and squatted down beside my go-kart.

“Know what we’re after?”
“Noppe. Want me to be runner today?” I said, jumping down from the go-kart.

She nodded and looked over towards an old wooden shed. “I overheard Granny talking on the phone to T.C. this morning before she left to go deliver newspapers. There’s a blue fifteen gallon bucket somewhere in his shed.”

“Do you know what’s in it?” I asked as I scanned all the junk laying around the yard.
“Nope, but it sounded important.”

I looked around the property one last time and then - ZOOM! I darted to the nearest pile of junk adjacent to the building. I crawled up to the top of the pile and crawled inside a tractor tire. I peeped my head out and looked back towards the woods where Lacey was now standing. She motioned for me to keep going towards the shed.

I laid back down inside my cubby hole and took a moment to regain my breath, but I couldn’t. The reality of what we were doing never really hit until after I had begun a mission. But when it did, it felt as though my heart was going to split out of my throat; this is what I craved, not the merchandise.

I lunged out of the tractor tire and ran towards the shed. Without stopping, I swung open the wooden doors and squeezed inside the room.

I paused and looked around. The only blue bucket I saw was sitting in the far corner; this had to be it. I opened the lid and immediately froze when I saw what was inside. The bucket was full of the wriggling bodies of crawfish. Squirming for air as there were too many to share the limited space. Frantic, I plunged around the shed looking for anything that would suffice as a fish bowl. This was the first time I had ever attempted to heist something living.

I finally found an empty glass container and began scooping out the creatures with my bare hands. The crawfish pinched my fingers as I pulled them one by one out of the cold murky water. No matter how much they hurt, I knew I couldn’t stop. It didn’t matter whose fault it was, I had to do whatever it took to get out of there for both our sakes. There were too many to carry so I filled the container as much as I could and ran out of the shed, making sure to leave everything close to the same position as it originally was.

Granny still wasn’t back from her newspaper route when we pulled back up to the house – giving us just enough time to hide the evidence until we could figure out what to do with them.

Lacey ran by my go-kart, grabbed the
container from the seat, and sprinted over to the concrete fishpond beside Granny’s house.

“D-Dump them,” I shouted, trying to push past what felt like a wad of cotton stuck in the back of my throat.

Right as Lacey threw the last crawfish into the pond Granny’s car pulled into the driveway. She opened the door and stepped out, holding her cell phone to her right ear.

“Yeah, you too,” she said as she walked around to the trunk of the car. “Thanks again T.C., that algae shit killed all my koi so I’m going to kill it and every damn else thing in there tonight.”

She opened the trunk and pulled out a blue bucket. Written on the side in bold letters was “Instant Kill Pond, the Ultimate Pond Restarter – 15 G.”
Natural Sciences
and
Engineering
Sea Level Rise Hazard Assessment for New Hanover County, North Carolina

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ABSTRACT
In the next one hundred years, sea level rise is going to significantly impact coastal communities across the globe. The rising seas will displace people from their homes and cause harm to the utilities and infrastructure that communities depend upon, thus creating the need for proactive planning measures that often rely on geospatial modeling. New Hanover County is located in southeastern North Carolina between the Cape Fear River and the Intracoastal Waterway. Given that the county is on a peninsula and is at a relatively low elevation, property and infrastructure are at a high risk of inundation. We used ArcGIS and modeling to determine what components of New Hanover County infrastructure are at risk of becoming inundated due to the combined effects of sea level rise and storm surges. We have identified possible areas of inundation to the year 2100 with conservative and precautionary sea level rise models to find what roads, stormwater systems, parks, superfund sites, and areas of land could become inundated. Due to their regional importance, we also analyzed in a spatially-explicit manner the extents to which the airport and port are likely to be affected. We conclude that New Hanover County will encounter significant planning and adaptation difficulties associated with inundation caused by the effects of sea level rise and storm surges, and that this work can help contribute towards alleviating them.

Global climate change is becoming an increasingly prominent issue as atmospheric CO$_2$ levels rise largely due to anthropogenic activity. One of the main impacts of climate change on coastal communities is sea level rise (SLR). A thorough understanding of this issue and advance planning measures are necessary steps in community adaptation to climate change. Not only will sea level rise affect the human landscape of a region, but it will also impact the natural ecosystem as a whole (Glavovic et al, 2015). It is important to perform hazard assessments in any region in order to identify and mitigate any potential risks for the future (McGuire, 2013). The average elevation in New Hanover County ranges from 0 meters to 23 meters, and as such is especially vulnerable to sea level rise. The ultimate goal of this project was to use GIS technologies to provide the residents and governments of the City of Wilmington and New Hanover County a report of areas that could potentially become permanently or temporarily inundated by sea level rise, storm surge, or flooding. This final report includes maps and summary tables of several impacted areas within the City of Wilmington, as well as for other key areas outside of the City limits such as Wrightsville Beach. This assessment was performed in cooperation with the
City of Wilmington and the Department of Geography & Geology through a Community Engagement Grant from University of North Carolina Wilmington.

**METHODOLOGY**

Using GIS, a hazard vulnerability assessment was performed on public services, transportation systems, and lifeline systems within New Hanover County to identify possible vulnerabilities to future sea level rise. Previous studies on SLR and its effect on certain infrastructures were conducted for the City of Wilmington in 2013. However, these studies focused primarily on wastewater infrastructure and only looked at impacts within the city limits of Wilmington (CHM2Hill, 2013). In order to maintain a generally uniform analysis between this assessment and the previous study, this assessment used the SLR scenarios developed by CH2MHIll, with the exception of the baseline 100cm SLR scenario because it was not included in the scenario data. The baseline scenarios only factor in the impact of SLR without the addition of storm surge. The scenarios that were utilized are as follows:

**Baseline SLR Scenarios:**

1. 40 centimeters (1.3ft) by 2100 – Historical SLR trend (N.C. Coastal Resources Commission, 2010)
2. 100 centimeters (3.3ft) by 2100 – Precautionary SLR trend (N.C. Coastal Resources Commission, 2010)

It should be noted that the precautionary SLR trend factors in the melting of the polar ice sheets, whereas the historical SLR trend is only based on historical sea level rise.

**Inundation Events:**

1. 10-year storm event flood elevation- Average storm surge and rain from a storm that has a 1 in 10 (10%) chance of occurring in any given year (CHM2Hill, 2013).
2. 100-year storm event flood elevation- Average storm surge and rain from a storm that has a 1 in 100 (1%) chance of occurring in any given year (CHM2Hill, 2013).

The bulk of this assessment was performed using ArcMap. A 30cm Digital Elevation Model (DEM) of New Hanover County was created by using the Mosaic tool in ArcMap to merge approximately 25 individual DEMs created by the National Oceanic and Atmospheric Administration (NOAA). This DEM was used to create the baseline 100-centimeter SLR scenario by using the Raster Calculator tool within ArcMap to identify land below 100 centimeters in elevation. After this, the Clip feature was used to clip the infrastructure data (roads, stormwater structures, parks, etc.) to get the areas that will be inundated by the 40-centimeter and 100-centimeter SLR scenarios. The output shapefiles provided the area, number of instances, or length of the inundated infrastructure being identified.

**RESULTS & AREAS OF CONCERN**

The major results of this assessment is organized into sections based on the affected infrastructure. The general extent of SLR in New Hanover County is presented first and the subsequent sections are presented in no particular order.

1. **General Extent**

   The general extent of SLR inundation in New Hanover County is referenced in Figure 1 and Figure 2. Figure 1 shows the extent of the 40-centimeter SLR scenario for all of New Hanover county. Figure 2 shows the extent of the 100-centimeter SLR scenario for the same region. In both figures, New Hanover County is delineated by a dashed line. The locator map in both figures show New Hanover County’s placement in the state of North Carolina.

2. **Roads**

   There are over 2,768 kilometers of roads
Figure 1. The overall extent of the 40-centimeter sea level rise scenario for New Hanover County, North Carolina. The sea level rise scenarios are layered so that the least amount of inundation (baseline 40cm SLR) is visible on top, with subsequent, higher inundation amounts layered underneath. The lighter shades indicate lower amounts of inundation and darker shades indicate higher amounts of inundation. New Hanover County is delineated by a dashed line. The locator map in the lower right corner shows the placement of New Hanover County in the state of North Carolina.
Figure 2. The overall extent of the 100-centimeter sea level rise scenario for New Hanover County, North Carolina. The sea level rise scenarios are layered so that the least amount of inundation (baseline 100cm SLR) is visible on top, with subsequent, higher inundation amounts layered underneath. The lighter shades indicate lower amounts of inundation and darker shades indicate higher amounts of inundation. New Hanover County is delineated by a dashed line. The locator map in the lower right corner shows the placement of New Hanover County in the state of North Carolina.
within New Hanover County. With a conservative SLR scenario of 40 centimeters, it is expected that 42 kilometers of roads will become permanently inundated. Road inundation increases to 30 kilometers under the 100-centimeter SLR scenario. This has the potential to interrupt transportation across the county and cut off roadway access to certain areas if the roads are not modified to either have a higher elevation or drain water away. Figure 3 shows some of the areas that would be majorly affected by the 40-centimeter SLR scenario. This figure depicts the area around Greenfield Park and the Port of Wilmington and their sections of road that would be inundated under each 40-centimeter SLR scenario. This area has approximately the same length of roads inundated under the 100-centimeter SLR scenarios.

The 60-centimeter difference in the two sea level rise scenarios is significant when considering the impact of storm surge associated with hurricanes and other large storm events. With a 40-centimeter SLR scenario, a 10-year storm would inundate 146 kilometers of roads. The same 10-year storm with a 100-centimeter SLR rise could inundate 203 kilometers of roads. It should be noted that this inundation is temporary and would recede back to 40-centimeter baseline level. A 100-year storm has the potential to inundate 275 kilometers of roads under the 40-centimeter SLR and 345 kilometers of roads under the 100-centimeter SLR. Figure 4 shows roads in the area around Wrightsville Beach that would be inundated by the 100-centimeter SLR scenarios. A locator map is used to show the area’s location in the county.

3. Stormwater Structures

Permanent inundation of stormwater systems could cause complications with stormwater management in the future. With a 40-centimeter SLR, approximately 29 kilometers of stormwater structures would be inundated. And with a 100-centimeter SLR, approximately 34 kilometers of stormwater structures would be inundated. This analysis does not factor in the depth of inundation, but only the areas that would be impacted.

During a hurricane or large storm event, these stormwater structures would be inundated with seawater due to the combination of long-term sea level rise and storm surge. During a 10-year storm, approximately 56 kilometers of stormwater structure would be inundated with a baseline sea level rise of 40 centimeters. There would be about 75 kilometers of stormwater structure that would be inundated with the baseline sea level rise of 100 centimeters. If a 100-year storm were to hit New Hanover County, approximately 98 kilometers of storm water systems would be inundated with the baseline sea level rise of 40 centimeters, and just over 107 kilometers of structure would be inundated for the same storm intensity with 100 centimeters of sea level rise. Figure 5 shows stormwater drainage infrastructure near Wrightsville Beach that would be heavily affected by the 100-centimeter sea level rise scenarios.

4. Parks

Parks and other outdoor public facilities are an important asset to the community. Not only do they provide recreation and education opportunities for residents, but they may also provide safe habitats for species of flora and fauna. Several parks throughout the city and county are vulnerable to sea level rise as they are situated near the Cape Fear River. As sea level rises, the water level of the Cape Fear River will rise, and in turn may permanently inundate the parks that are near its banks. Figure 6 shows four parks in Wilmington that will be inundated under the 40-centimeter SLR scenarios. The overall average elevation in this figure ranges from 0 meters to 4 meters, and the parks pictured will experience anywhere from .3 acres to 13 acres of inundation under the 40-centimeter SLR scenarios. Although this may not seem like a significant amount of area lost to flooding, many of these parks will have their properties flooded out almost entirely.

One of the most affected parks in the county will be Greenfield Park (Fig. 7). The average elevation at this park is between 0
Figure 3. Inundation of roads near Greenfield Park and the Port of Wilmington in New Hanover County, North Carolina. The locator (lower left) and index (upper left) maps on the left show the relative location of the area in the state and county, respectively. The map of the roads affected is listed as follows: baseline 40cm SLR (upper right), 40cm SLR/10-year storm event (center right), 40cm SLR/100-year storm event (lower right). The roads shown in thick black lines are the roads that will be inundated in each scenario. It should be noted that approximately the same amount of roads are inundated in this area under the 100cm SLR scenarios.
Figure 4. Inundation of roads near Wrightsville Beach in New Hanover County, North Carolina. The locator (lower left) and index (upper left) maps on the left show the relative location of the area in the state and county, respectively. The map of the roads affected is listed as follows: baseline 100cm SLR (upper right), 100cm SLR/10-year storm event (center right), 100cm SLR/100-year storm event (lower right). The roads shown in thick black lines are the roads that will be inundated in each scenario. It should be noted that most of the roads in Wrightsville Beach will be inundated during any storm event.
Figure 5. Inundation of stormwater channels near Wrightsville Beach in New Hanover County, North Carolina. The locator (lower left) and index (upper left) maps on the left show the relative location of the area in the state and county, respectively. The map of the affected areas is listed as follows: baseline 100cm SLR (upper right), 100cm SLR/10-year storm event (center right), 100cm SLR/100-year storm event (lower right). The structures shown in thick black lines are the stormwater channels that will be inundated in each scenario.
Figure 6. Parks in New Hanover County, North Carolina experiencing inundation under 40cm SLR scenarios. The index map on the right shows the area’s location in the county. The park parcels are outlined in thick, dark lines. The parks shown on this map will experience anywhere from .3 acres to 13 acres of inundation under the 40cm SLR scenarios. Although this may not seem like a significant amount of area lost to flooding, many of these parks will have their properties flooded out almost entirely.
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<th>Park Name</th>
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<th>Acres Inundated (10yr Storm)</th>
<th>Acres Inundated (100yr Storm)</th>
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Table 1. Acreage of Parks in New Hanover County inundated under 40cm SLR scenarios.

Sydney Bohn and Evan Hill

meters and 2.5 meters. Although much of the park consists of Greenfield Lake itself, the park as a whole is at great risk for becoming completely flooded as sea levels rise. The park will experience between 111 and 179 acres of inundation under the 100-centimeter SLR scenarios. Tables 1 and 2 list all of the parks in Wilmington (including Greenfield Park) that will experience inundation during both 40-centimeter and 100-centimeter sea level rise scenarios. Parks that are not inside the City limits but reside in New Hanover County are also included in this list.

5. Wilmington International Airport

The Wilmington International Airport has served the Wilmington community for many years. The airport serves as a major transportation hub for both domestic and international flights, as well as for commercial activities. Both the 40- and 100-centimeter sea level rise scenarios have the potential to affect the airport’s property. These scenarios are depicted in Figures 8 and 9. The average elevation for the airport property ranges from 0 meters to 10 meters. The lower elevations are mostly contained near the southern part of the property.

Although the scenarios do not show sea level rise having an effect on the major airport terminal or the major runways, it does have the potential to affect some of the minor runways and administrative buildings. The majority of these areas lie along the southern edge of the airport property. Overall, the airport property is expected to lose 185 acres (Fig. 8) to 255 acres (Fig. 9) to either permanent or temporary inundation.

6. Superfund Sites

The Superfund program, established by Congress in 1980, is designed to help clean up sites contaminated by hazardous pollutants or chemicals that pose a threat to human health. The Environmental Protection Agency (EPA) identifies these hazardous sites throughout the country (Hird, 1993). New Hanover County is home to 14 Superfund
sites, both active and inactive, many of which are located along the Cape Fear River (US Environmental Protection Agency, 2016). Most of the Superfund sites in New Hanover County have completed the cleanup process and no longer pose a major health hazard. However, there are still several Superfund sites in the county that are actively undergoing cleanup and may still pose a hazard to the community. One such site is the Southern Wood Piedmont Co. site (Fig. 10).

Although the projected sea level rise is not expected to be reached until 2100, that does not mean that the impacts will not occur before that date. Sea level rise is a gradual change that occurs over many years and decades. The concern with the Superfund sites in terms of sea level rise is that the hazardous chemicals and pollutants at these sites may leach into the water supply or ground water before cleanup efforts can be completed. The Southern Piedmont Wood Co. site is positioned in such a way that the site will be 100% inundated within just the baseline 40-centimeter sea level rise scenario. The is because the average elevation at this site only ranges from about 0 meters to 1.5 meters. This inundation is depicted in Figure 10.

If cleanup efforts are not completed at this site before the hazardous areas become inundated, it is possible that contaminants could leach from the site. Although the site is classified as Superfund, the Southern Piedmont Wood Co. site is not on the EPA’s National Priorities List, which means that the contaminants or amount of contamination at this site is not classified as posing a significant or immediate impact on human health (US Environmental Protection Agency, 2016). The contaminants present a definite health hazard, but are not dangerous enough to the public that the EPA has to take drastic action to remediate the site.

7. Port of Wilmington

The Port of Wilmington is a major commerce hub and one of the few large shipping ports located in the South Atlantic. The port handles upwards of 4.5 million tons of cargo in a single year. Although the port is

<table>
<thead>
<tr>
<th>Park Name</th>
<th>Acres Inundated (100cm Baseline)</th>
<th>Acres Inundated (10yr Storm)</th>
<th>Acres Inundated (100yr Storm)</th>
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Table 2. Acreage of Parks in New Hanover County inundated under 100cm SLR scenarios.
Figure 7. Parks in New Hanover County, North Carolina experiencing inundation under 100cm SLR scenarios. The index map on the right shows the area’s location in the county. The park parcels are outlined in thick, dark lines. The parks shown on this map will experience anywhere from .3 acres to 16 acres of inundation under the 100cm SLR scenarios. Greenfield Park will have the highest amount of area inundated out of all the parks in New Hanover County. Greenfield Park will experience between 111 and 179 acres of inundation.
Figure 8. Inundation of the Wilmington International Airport (ILM) under 40cm SLR scenarios. The index map in the upper right shows the location of the airport in New Hanover County, North Carolina. The majority of the airport’s property, including the main terminal will remain unaffected by these scenarios. However, other minor runways and several administrative buildings will most likely be inundated.

Figure 9. Inundation of the Wilmington International Airport (ILM) under 100cm SLR scenarios. The airport’s property boundaries are shown as a thick, dark line. The index map in the upper right shows the location of the airport in New Hanover County, North Carolina. Although much of the baseline 100cm inundation here is similar to the 40cm inundation, some areas will experience a wider extent of inundation during storm events.
not managed by the City itself, any effect that sea level rise may have on the port may ultimately effect the community economically. With both sea level rise scenarios (Fig. 11 & Fig. 12), it is quite apparent that the Port will be inundated, whether it be through storm events or just baseline sea level rise. The average elevation for the Port ranges from 0 meters to 4.5 meters. The lower elevations in this area are situated along the northern end of the property. Most of the buildings and storage facilities on the Port’s property will be severely impacted by sea level rise. The northern section of the Port’s property will most likely be heavily inundated, even with the baseline 40-centimeter sea level rise scenario. The extents of the 40-centimeter and 100-centimeter SLR scenarios are depicted in Figures 11 and 12, respectively.

8. Wrightsville Beach
The Wilmington area is known for its outstanding downtown and pristine beaches. Although these are not within city limits, Wilmington benefits tremendously from the tourism the beaches generate. The appeal of Wrightsville Beach and other neighboring beaches impacts the citizens of Wilmington, so the wellbeing of beach towns should be considered when planning for future development in Wilmington. The average elevation at Wrightsville Beach ranges from 0 meters
to 5.5 meters but the majority of the town is less than 2 meters in elevation.

Figures 13 and 14 show the expected inundation of Wrightsville Beach for 40-centimeter and 100-centimeter sea level rise scenarios, respectively. Significant portions of Wrightsville Beach will inundate under both 40-centimeter and 100-centimeter SLR scenarios. It should be noted that under the 100-centimeter SLR scenarios (Fig. 14), Wrightsville Beach will be inundated almost entirely. Because coastlines are dynamic and constantly moving, it is entirely possible that Wrightsville Beach could be washed away completely during a 100-year storm event.

Wrightsville Beach and other beach communities are at the highest risk of being impacted by sea level rise. Wrightsville Beach is a barrier island, and as such, is subject to sea level rise impact on every side. This causes other more dynamic issues, such as coastal erosion. For planning for sea level rise in our beach communities, research will need to be done on the best methods to protect our shorelines from erosion, and to prevent the community’s developments from becoming inundated. This research is also critical to the real estate market in Wrightsville Beach, as it will inevitably become riskier to build and live in homes near the beach.

**SUMMARY AND CONCLUSION**

In the next century, New Hanover County and the City of Wilmington will face challenges with infrastructure due to rising sea levels. The major concerns for the infrastructure in this area are multifaceted: many systems are not designed to operate properly when flooded and water, especially saltwater, can cause the systems and facilities to degrade faster than they would normally (CHM2Hill, 2013). Coastal communities are among the most vulnerable areas in terms of sea level rise and future storm events (McGuire, 2013). Portions of the Port of Wilmington and Wilmington International Airport are vulnerable to sea level rise due to their adjacency with bodies of water that are connected to the ocean. Portions of these facilities and the land they are situated on will likely become permanently inundated by higher water levels.

Even under conservative (40-centimeter) sea level rise scenarios, many roads and stormwater systems in New Hanover County are at serious risk for becoming permanently inundated. It should also be noted that there is a risk that certain Superfund sites throughout the county may be inundated by sea level rise. In particular, the active Southern Piedmont Wood Co. site near downtown would be completely inundated even at the baseline SLR of 40 centimeters. This could be particularly hazardous if contaminants contained at these types of sites made their way back into the area’s waters. Other areas outside of the City limits, such as Wrightsville Beach, may also experience severe complications related to future sea level rise.

The authors hope that projects like this, using GIS and sea level rise data will be used for planning and development in New Hanover County, in order to identify areas that are at high risk of permanent and temporary inundation.
Figure 11. The Port of Wilmington, North Carolina under 40cm SLR scenarios. The index map in the upper right indicates the port’s location in New Hanover County. The port property boundaries are indicated by thick, dark lines. The structures located at the port are labelled by type in the map legend.
Figure 12. The Port of Wilmington, North Carolina under 100cm SLR scenarios. The index map in the upper right indicates the port’s location in New Hanover County. The port property boundaries are indicated by thick, dark lines. The structures located at the port are labelled by type in the map legend.
Figure 13. Wrightsville Beach, North Carolina under 40cm SLR scenarios. The baseline 40cm SLR will greatly impact Wrightsville Beach’s shoreline, but the largest impact will come from the storm events.
Figure 14. Wrightsville Beach, North Carolina under 100cm SLR scenarios. The baseline 100cm SLR will significantly impact Wrightsville Beach’s shoreline, but the largest impact will come from the storm events. It should be noted that under both the 10-year and 100-year storm events, Wrightsville Beach will be inundated almost entirely.
ACKNOWLEDGEMENTS

We would like to thank Dr. Narcisa Pricope for her guidance on this project. We would also like to especially thank Phil Prete from the City of Wilmington for consulting with us at the outset of the project and providing us with city infrastructure data, as well as CH2M Hill for providing us with sea level rise scenarios datasets. This work was made possible through a grant to Dr. Pricope from UNCW’s Office of Community Engagement. We ultimately appreciate everyone that took time to assist us with this work.

REFERENCES


The Chip ‘n’ Ship: A Prototype Rock Chip Sampling Tool for Use on Microgravity Bodies

Jacob Brooks, Michael Cantor, Matthew Ickowski, Simeon Simeonides, Hallie Stidham and Alan Vasquez Soto

High Point University

Faculty Mentor: Brad Barlow and Aaron Titus
High Point University

ABSTRACT
In response to NASA's Micro-g Neutral Buoyancy Experiment Design Teams program challenge, a rock chip sampling device called the Chip ‘n’ Ship was designed, constructed, and tested. It was developed for use on microgravity bodies, primarily asteroids. The device incorporates a commercially-available, unmodified pneumatic hammer mounted inside a section of aluminum housing. It also features three interchangeable collection cartridges, specifically engineered to mitigate cross-contamination between sampling sites. The Chip ‘n’ Ship was subjected to functional testing by the Neutral Buoyancy Laboratory dive team at NASA’s Johnson Space Center in Houston, Texas in August 2015. The Chip ‘n’ Ship chipped a variety of rock samples successfully but could use general improvement to the sample collection mechanism and sealing of the sample inside the collection unit.

When exploring the Moon, astronauts relied solely on hand tools to extract and collect rock chip samples. This process is labor intensive and inefficient, and National Aeronautics and Space Administration (NASA) officials are seeking alternative tool designs to develop a more efficient rock chip sampling process [1]. Such techniques should be established before NASA moves forward in planning and executing missions to asteroids. Due to safety and transportation restrictions, the design of any new tool must minimize risk of harm to the user while not significantly encroaching on mission payload limitations.

As part of the search for new ideas and engineering innovation, NASA established the Micro-g Neutral Buoyancy Experiment Design Teams (Micro-g NExT) program as part of their Microgravity University (formerly Reduced Gravity Education Flight Program, or RGEFP) outreach initiative. Micro-g NExT challenges undergraduate students to “design, build, and test” a device or simulant that addressed an “authentic, current space exploration problem” selected by NASA engineers [2]. The program encourages participants to innovate with hands-on engineering design and functional test operations in the simulated microgravity environment of NASA’s Neutral Buoyancy Lab (NBL) facility. Professional NBL divers test all tools that are accepted into the program, under the direction of the student teams via radio communications.

Specifically, the Micro-g NExT program
challenged teams to design a tool that astronauts could use to break off samples from an asteroid or other large rock body while safely capturing and containing them for the return to Earth. In this challenge, a chip sample is defined as one that is forcibly removed from or broken off of a larger parent body. All submitted devices must be designed for use in a microgravity environment and be able to obtain three separate chip samples without cross contamination. In order to meet all of NASA’s guidelines and design specifications [2], rock chip sampling devices had to be able to create and contain rock chips no larger than approximately 1”x1”x1”, capture and retain at least one chip sample per sample site (three separate sites total) without cross contamination between sites, be driven manually, pneumatically, and/or hydraulically only, and provide for storage of samples independent of one another. Aside from these main requirements, the devices also had to prevent chipping debris from impacting the crew member, work with diverse surfaces (rough, concave, flat, and convex), be compatible with a chlorine water environment (for NBL testing), weigh less than 15 pounds, be ambidextrous where the chipping task shall be capable of one-handed operation, and have a tether attachment point.

Teams whose proposals addressed these requirements effectively were granted the opportunity to build their proposed devices and travel to Johnson Space Center to test them in a simulated microgravity environment. Constructed devices were screened for safety considerations through the submission of Technical Experiment Design Packages (TEDPs), which were reviewed by the NASA NBL safety panel and dive team before permission was granted to enter the NBL. Devices were then tested in the NBL for functional performance; teams received feedback on design elements in addition to suggestions for potential improvements.

The High Point University Panther CLAWS (Chipping Loose Asteroids with Science) team, comprised of six physics and computer science majors, designed and tested a tool called the Chip ‘n’ Ship to meet all of the aforementioned design criteria. The team’s primary concern was successful chipping and collection, but also focused heavily on mitigating the risk of cross-contamination as much as possible [3]. In the sections that follow, the details of the design process and results of device testing, with a focus on both the Chip ‘n’ Ship’s strengths and shortcomings, are discussed.

METHODS & DEVELOPMENT

Early Proposed Concept

For powered chipping, the use of compressed air to power a pneumatic hammer–chisel system was determined to be most feasible for use in the NBL and in space. The selection of an unmodified commercial air hammer was important during safety presentations to NASA officials. By using an unmodified hammer, manufacturer testing data was used to support safety claims on the device while also avoiding stringent re-characterization tests that would need to be completed had the air hammer been modified. The proposed Chip ‘n’ Ship design boasted two unique characteristics. First, it utilized hemispherical steel spheres, driven by a pneumatic hammer, that rotate rapidly in a “biting” motion to chip and contain rock samples; this idea was inspired by nature [4]. These rotational chipping elements would be more easily secured to contain the sample after the chipping action was completed. Second, the design also incorporated a “cartridge” element to mitigate cross-contamination risk. The cartridge was a self-contained individual unit consisting of a primary chipping element and a containment area. These cartridges could be loaded and unloaded onto the main body of the tool (Figure 1). When loaded, the rotational chipping elements interacted with the pneumatic hammer, which ensured that the hammer was never exposed to a sampling site surface.

Preliminary “Rotational Force” Testing

A test block was constructed from sections
of wood to hold prototype aluminum quarter spheres in place along an axle, which allowed the team to test the ability of the chipping elements to chip a rock sample. Specifically, the device’s ability to translate linear motion (the driving hammer) into rotational motion (the quarter-spheres chipping) was investigated. Initial tests indicated that the prototype did not permit enough force from the driving hammer to be translated into effective force for chipping a rock sample. During this testing, the rings on the spheres that attached them to the axle were warped and ultimately broke due to stress. The stress point at the connection of the quarter spheres to the axle was very weak in the aluminum shells, so steel quarter-spheres were fabricated for the same functional test. While the ring through which the axle passed remained intact during the testing of the steel quarter-spheres, they were unable to chip samples from the rock. These results indicated that the use of the rotational system for completing the chipping action was not a feasible approach, and the design was appropriately revised.

Element Revision & Computer-Aided Design (CAD) Modeling

The initial design was modified to utilize the pneumatic hammer itself as the direct driver for the chipping action. A hardened steel chisel blade was modified by removing the cutting feature and affixing a collar to the end of the chisel shaft; this modified chisel was fixed with the hammer and never removed. This “driver piston” chisel actuated other chipping chisel bits, which were fixed in individual cartridges using a spring and collar system. The quarter spheres were modified to act as cartridge doors to contain the sample after a successful chipping action.

Initial designs of the device consisted of a series of crude sketches with no concrete dimensions. After a final design was formulated, dimensions were added for drawing and the design in AutoCAD. Sections of the design were 3-D printed for functional testing before metal parts were ordered or developed. The three dimensional model highlighted weak points that needed to be revised, as well as ways to modify moving parts for optimal...
Final Prototype Design

The main portion of the working prototype featured a pneumatic air hammer secured by metal collars and bolted in place inside of a section of aluminum housing. The hammering action was normally activated by squeezing a hand trigger. However, after reviewing our TEDP, NASA officials questioned how a stuck trigger malfunction would be handled in the test environment and in space. Additionally, there was some concern that an astronaut’s bulky glove could become pinched by the lever itself during operation. To address these concerns, we elected to permanently force a stuck trigger as part of the final design and develop a different method of controlling air flow. A ball valve was affixed to the air inlet on the hammer to provide simple and effective user control of the air flow. A six-inch length of pneumatic pipe was affixed to the ball valve to extend the grip of the device, providing greater maneuverability and leverage (as per the suggestion of the NBL dive team members prior to NBL testing).

After this change was implemented, U-shaped aluminum pieces were attached to each cartridge to allow the user to open the cartridges by “pushing” the device into the surface to be chiseled. The doors were affixed to these U-shaped “legs” initially with braided wire, and were automatically closed using an interior spring system (Figure 4). After extended use, the wire became bent and would not easily return to a relaxed state, thus preventing the doors from closing properly. The thread was exchanged for high-tension fishing line, which retained its shape and length more consistently and predictably.

Figure 2: CAD drawing of early cartridge design. Quarter-sphere doors house the chipping element and are operated by the lever system affixed to the outside of the cartridge. The lever system was replaced for functional purposes.
The final cartridge design was the ultimate result of a number of increasingly refined and functionally-capable design iterations. Important design implementations included: integration of the chisel bit and shock bracing system into the infrastructure of the cartridge, automation of cartridge door opening and closing, and implementation of a butterfly latch system for secure temporary attachment to the main body of the tool (Figure 5). The cartridge was designed around a three-inch thick cylinder of aluminum. Steel quarter-sphere doors were affixed to the cylinder with hinges and a spring-loaded closing mechanism. An aluminum plate was affixed to opposite sides of the cylinder perpendicular to the hinges. Two bolts were affixed to both sides of each plate, and U-shaped aluminum “legs” were fitted over these bolts to slide freely along a channel cut in the legs. Metal brackets at the top of the legs prevented warping of the legs, and provided a central location for an attachment point for the high-tension fishing line. Holes were

**Figure 3:** CAD drawing of initial tool design, with cartridge affixed to main body of the device.

**Figure 4:** Open cartridge. Chipping element can be seen in the center. The spring closing mechanism of the doors can be seen affixed to the sides of the chisel bit.
drilled in each of the steel doors on the cartridge, and fishing line was attached between the door and the attachment point on the leg bracket. A hole was drilled in the center of the aluminum cylinder for the placement of the chipping chisel. The hardened steel industrial stock chisel was shortened and placed into the hole in the cylinder. Collars and shock springs were fixed to both sides of the chisel bit to maintain the reciprocating action of the chisel while also keeping the chisel fixed in the cartridge (Figure 4). This design was replicated twice after completion and revision of the prototype, for a total of three identical interchangeable cartridges.

A key component in the automated door function was the implementation of a bracing bolt on each cartridge that ensured that the two independent U-shaped “legs” functioned simultaneously (Figure 5). The sliding mechanism consisted of the legs sliding along bolts through a channel in the legs. This mechanism was prone to jamming induced by excess friction between the channel in the legs and the bolts. The jamming occurred frequently because the legs were free to move independently and could not slide simultaneously along the rails. By fixing an adjustable bolt between the legs on each cartridge, leg pairs were forced to move simultaneously. The tightness of the bolt on each leg could be fine-tuned with minor adjustments to the affixed lock nuts, which in turn adjusted the spacing between the legs. The addition of NASA-approved water-resistant lubricant greatly increased the reliability of the sliding leg mechanism and other moving parts on the device.

After construction of the main housing and the three cartridges was completed, all rough and sharp edges on all metal surfaces (with the exception of the chisel blade) were appropriately smoothed, and all exposed screws and bolts were smoothed and covered with plastic caps for additional user protection. Tether rings were appropriately positioned on the main body of the tool and each individual cartridge after construction was completed. These rings were located away from all moving parts and away from surfaces designed to interact with the surface site from which samples are taken. Remaining edges, pinch

Figure 5: Side view of open cartridge in operational position. Butterfly clip for attachment to the main body (top) and U-shaped legs sliding on bolts are visible on the left and right sides.
points, and other potential hazards were clearly labeled on the device. The final design was taken to the NBL at Johnson Space Center for testing in August 2015 (Figure 6).

**ANALYSIS**

In order to demonstrate to NASA officials that the Chip ‘n’ Ship was safe for use by their NBL divers, extensive and varied device performance characterization was required. The TEDP was submitted to NASA several weeks prior to the team’s testing window as a mandatory document for the device safety screening protocol and discusses the hardware design, analysis and testing of the device, operations plan for using the device, and a hazard analysis table. The primary focus of the TEDP was functional performance data collection and analysis. Ambient 1-g testing was performed at various stages during the construction process in dry and submerged conditions. Data analysis focused on force transfer from the hammer to the chisel and force transfer from the chisel to the sample site separately. These force tests were conducted using Vernier force plates and the LoggerPro data analysis software. Data recording started at the initial applied force from the user before oscillations began.

**Hammer Force Plate Test**

Applied inlet air pressure of 90 PSI (Table 1) was used to measure peak force and root mean square force over a brief actuation period (Figure 7). Frequency and amplitude of force oscillations were analyzed, and a simple sinusoidal curve was fitted to the data to provide a rough model of hammer operation (Figure 8). The simple curve fit provided an excellent model over short time frames, but the oscillatory behavior observed in the applied force was more accurately described as a superposition of multiple sinusoids with different amplitudes and frequencies. Fast Fourier Transform (FFT) analysis was performed to determine peak frequencies of oscillation, with the principal peak frequency being approximately 62 Hz (Figure 9). The focus was the peak frequency, so harmonics were not investigated further.

**Chisel Force Plate Test**

Applied inlet air pressure of 90 PSI (Table
Table 1: Peak and root mean square (RMS) force of the pneumatic hammer operated at 90 PSI in 5 separate tests. *Peak force was highly dependent on the force the user exerted in pushing down on the force plate before the test begins. As peak force changed, RMS force remained fairly consistent.

<table>
<thead>
<tr>
<th>Applied Inlet Pressure (PSI)</th>
<th>Peak Force* (N)</th>
<th>RMS Force (N)</th>
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Figure 7: Pneumatic hammer force oscillations.
Figure 8: Close view of measured force oscillations of the hammer juxtaposed against a sinusoidal model.

Figure 9: FFT analysis of hammer force oscillation testing.
NBL Acoustic Testing

The final preliminary test was an acoustic test before the device could be approved for underwater use in the NBL by NASA divers. The Chip ‘n’ Ship was lowered into the water and activated by a certified NBL diver, while another diver held a decibel sensor 3 feet away from the device. The sound intensity limit for operation in the pool was 50 dB; if the device exceeded this limit, it would not be allowed into the water as it could cause damage to other equipment or could cause hearing damage to the divers. The difference in sound intensity in water compared to air is approximately 61.5 dB, meaning that the underwater limit of 50 dB underwater equates to around 121.5 dB in air [5]. The Chip ‘n’ Ship operated in the range of 30-40 dB underwater, hitting the benchmark for other pneumatic devices that the engineers have allowed into the pool in the past.

RESULTS FROM NASA NEUTRAL BUOYANCY LAB TESTING

After NASA officials confirmed that the Chip ‘n’ Ship met all safety requirements, the Panther CLAWS team was offered a thirty minute time slot to test the device’s functionality in the NBL with the assistance of the facility’s dive team. During this time, the team was free to lead the divers through a series of varied functional tests performed in the simulated microgravity environment. The team briefed the divers on the operation of the Chip ‘n’ Ship poolside, and then the NBL dive team executed underwater testing.

2) was used to measure peak force and root mean square force over a brief actuation period. Frequency and amplitude of force oscillations were analyzed, and a simple sinusoidal curve was fitted to the data to model chisel operation. FFT analysis revealed similar peak frequency, amplitude, and phase measurements for the chisel testing, offering firm evidence that the driving hammer and chipping chisel operate fully in concert. No significant drop in force was seen between the hammer and the chisel, and it was concluded that the selected design was effective in maintaining high frequency force oscillations of the chisel (Figure 10). In the two tests shown in Figure 10, force plate analyses of the hammer-chisel assembly were conducted using a crude tape system because the characterization data was ultimately used to inform the final design and internal bracing system used. FFT analysis showed a similar oscillation frequency of about 62 Hz (Figure 11).

After characterizing the pneumatic actions, the team tested the device’s functionality in a campus lab with rock samples to optimize the protocol for the chipping action. Brick, concrete, and rhyolite were selected as asteroid sample simulants to provide a range of different attributes to increase the robustness of the design. Rock simulants were tested in ambient environmental conditions and also submerged. The Chip ‘n’ Ship was able to remove chips from all three sample types in both air and water. The underwater tests confirmed that the hammer would operate properly in the NBL for an extended period of time without loss of functionality.

<table>
<thead>
<tr>
<th>Applied Inlet Pressure (PSI)</th>
<th>Peak Force (N)</th>
<th>RMS Force (N)</th>
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<tbody>
<tr>
<td>90</td>
<td>92.13</td>
<td>91.0</td>
</tr>
<tr>
<td>90</td>
<td>70.61</td>
<td>86.9</td>
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Table 2: Peak and root mean square (RMS) force of the cartridge chisel actuated by the pneumatic hammer at 90 PSI.
**Figure 10:** Force plate testing of the chipping chisel when actuated by the pneumatic hammer. Two tests are shown; the tape holding the test assembly tore during the second test, which caused the force significant drop off seen in the curve.

**Figure 11:** FFT analysis of cartridge chisel force oscillation testing.
After the exchange, the divers continued to perform additional chipping testing for the new cartridge and collection testing.

The Panther CLAWS team asked the divers to test the collection capabilities of the Chip ‘n’ Ship after completing the chipping tests. The simulant bed, full of smaller rocks and chips, provided an excellent area to test this function. The Chip ‘n’ Ship was able to successfully collect samples, but required some unorthodox manipulation in order to do so. The collection mechanism was based on a true micro-gravity environment where any chipped rocks would likely not remain on the surface. Even in the NBL, gravity was still a significant factor on dense objects like the rock simulants. The first series of collection attempts was executed in a linear vertical fashion (perpendicular to the surface), where the U-shaped legs slid along the bolts as intended and opened and closed the doors accordingly. This caused the doors to shut as the tool was retracted from the surface. During these attempts, gravity pulled the chips down so that the Chip ‘n’ Ship could not collect them as it was pulled away from the surface. Communicating with the divers, the team suggested that an approach be tested in a way that positioned the Chip ‘n’ Ship longitudinally parallel to the surface. This approach led to a successful collection attempt. By pushing the legs of the device into the simulant bed at nearly parallel, the doors closed on sample even when the tool was retracted. Instead of relying on suspension of the chips, the test was able to rely on the sheer number of chips and small rocks in the simulant bed in order to make sure the cartridge doors closed with a sample inside. Essentially, the amount of rock chips in the bed were pushed into a mound by the divers, which offered enough resistance to engage the rail mechanism that moved the legs and opened the containment doors.

After design modifications and TEDP testing, this underperformance in collection was to be expected. The primary issue with sample collection was the retracting closure of the containment doors. As the device is functional testing of the device. During this time, the Panther CLAWS team directed divers through individual tests from the NBL control room and tracked the testing progress on video monitors.

The divers were first asked to test the chipping capabilities of the Chip ‘n’ Ship. In the NBL testing area, the dive team had set up a number of rock testing surfaces, including one developed by another team who engineered a solution to a challenge focused on developing an asteroid surface simulant. The rock simulant bed contained four rock simulant types along a hardness gradient [6,7]. The Chip ‘n’ Ship successfully chipped all four rock simulants in the bed. Additionally, there was a single large rock (approximately 9” X 9” X 9”) included in the NBL for chipping testing. In many ways, this large rock was a better representation of an asteroid surface because the rock simulants in the bed were not large, solid surfaces, but rather a series of homogenous smaller rock collections [8]. The Chip ‘n’ Ship successfully chipped off useful samples from the large rock as well, a great indicator of potential for success on a mission to space.

One issue observed during the underwater testing of the chipping function involved jamming of the U-shaped legs along the bolts. The system was lubricated and designed to move smoothly to provide consistent opening and closing of the cartridge doors; however, the first cartridge that was tested malfunctioned and jammed in such a way that the doors would not close fully. At this point, it was determined that the divers needed to switch cartridges, which presented an opportunity to test the cartridge interchange function of the Chip ‘n’ Ship. With two other available cartridges, the divers were asked to unclip the butterfly clips, exchange the malfunctioning cartridge with an alternative cartridge, and secure the butterfly clips with the new cartridge. The exchange went very smoothly, as the Chip ‘n’ had position indicator arrows drawn on both the main body and the cartridges that were to be aligned while affixing a new cartridge to the main body.
retracted from a surface, the doors close automatically as a response. In an environment with gravitational forces present, rock chips do not remain suspended in space and fall quickly back to the sample surface. In a true micro-gravity environment, these rock chips would fall back to the surface more slowly, increasing the effectiveness of the retracting capture method. The divers offered a similar assessment, stating that the design was clever and easy to use, and that the collection issue would not be present if the device were operated in a true micro-gravity environment, such as the surface of an asteroid. Most importantly, the device was able to chip off rock samples from different sites without cross contamination.

The test divers and NASA officials deemed the testing experience of the Chip ‘n’ Ship in the Neutral Buoyancy Lab to be highly successful. The chipping action was successful on various rock and rock simulant surfaces. The design was highly ergonomic, and the dive team complimented the user-friendliness of the device. Tether point selection played a significant role in maximizing maneuverability while minimizing risk of entanglement with tether lines.

DISCUSSION

The NBL divers gave the Panther CLAWS team positive feedback regarding the handling and operation of the Chip ‘n’ Ship. During post-testing presentations and reviews, NASA officials from the Extravehicular Activity (EVA) team closely examined the design. The interchangeable self-contained cartridges and automated door mechanisms were both popular design elements. The EVA team will consider the design moving forward in preparation for future missions, and perhaps incorporate elements of the Chip ‘n’ Ship design into the final design of their EVA rock chip sampling tool. The team’s work on the Chip ‘n’ Ship could potentially influence NASA engineers and ultimately contribute to the success of future missions, including an eventual manned mission to Mars or asteroids.

There are several design elements of the Chip ‘n’ Ship that could be significantly improved. Independent opening and closing of each of the two quarter-sphere containment doors on each cartridge would allow for a greater range of operational angles and would improve sample collection success rate. Additionally, a more robust solution to the door actuation element should be investigated. Using high tension fishing line has proven to be successful, but risks fraying and breaking with extended exposure to rock shards. One possible solution to such a problem is a mechanical metal arm that is rigid and will not stretch or fray, positioned where it will not risk being bent or otherwise damaged. A more effective method of ensuring that the doors of each cartridge remain secured after sample collection would be an improvement as well. A magnetic locking system and a simple latch system are both potential candidates for such a modification.

Additionally, operating the Chip ‘n’ Ship in a true micro-gravity environment would likely lead to better performance. Rock chips would not immediately fall back to the surface, and the retractable collection method would have a more consistent success rate. The Chip ‘n’ Ship significantly reduces the effort from the operator in order to achieve a successful sample collection. Even for a lunar mission, the acceleration due to gravity is roughly one sixth of the acceleration on Earth. In a microgravity environment, the acceleration due to gravity is even lower. However, the test in the NBL was useful for confirming the functionality of the chipping action and the usability of the device in terms of ergonomics and weight.

CONCLUSION

In response to NASA’s Micro-g NExT program challenge, a team of High Point University physics majors designed and constructed a handheld device called the Chip ‘n’ Ship for chipping off and collecting surface samples from asteroids and other
to further improve upon the Chip ‘n’ Ship design, with a focus on the problems associated with the collection performance. Some of the team members have graduated and are no longer available to help hands-on with project modifications. However, the testing at NASA generated a significant amount of interest in the department, so it is likely that a new team will come together in the future and may choose to modify and improve the Chip ‘n’ Ship as their project. Until then, NASA will use concepts from the Chip ‘n’ Ship, along with other designs submitted to the Micro-g NExT program, to develop usable EVA tools for astronauts to deploy on future space missions.

The practical skills the Panther CLAWS team acquired through the development and construction of the device will be helpful in further instrument design and testing. In the future, a new student team will be assembled to further improve upon the Chip ‘n’ Ship design, with a focus on the problems associated with the collection performance. Some of the team members have graduated and are no longer available to help hands-on with project modifications. However, the testing at NASA generated a significant amount of interest in the department, so it is likely that a new team will come together in the future and may choose to modify and improve the Chip ‘n’ Ship as their project. Until then, NASA will use concepts from the Chip ‘n’ Ship, along with other designs submitted to the Micro-g NExT program, to develop usable EVA tools for astronauts to deploy on future space missions.

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REFERENCES


An in situ study of seasonal dissolved organic carbon and nutrient fluxes from a Spartina alterniflora salt marsh in North Carolina, USA

ABSTRACT
Salt marshes are among the most productive and biogeochemically active ecosystems on Earth. While they are known sources of dissolved organic carbon (DOC), and organic and inorganic nutrients (including nitrogen, N, and phosphorus, P) to the coastal ocean, it has not been well quantified experimentally. The purpose of this study was to quantify seasonal DOC and organic and inorganic N and P fluxes from a fringing temperate salt marsh in North Carolina, USA. This experiment was conducted using in situ benthic microcosm chambers in which seawater samples were collected during ebbing tides over 4.5 hours. Water samples were analyzed for DOC and organic and inorganic nutrient concentrations over time, and fluxes from vegetated and non-vegetated marsh sediments were calculated. Results showed that there were no significant differences in fluxes between vegetated and non-vegetated sediments within the same season. However, sediments were a minor source of DOC, N, and P in July compared to a significant sink in December. These data suggest that the remineralization of organic matter occurs more strongly in the winter with a more active microbial loop. Results also provide insight as to how environmental variability may affect coastal biogeochemical cycles.

Salt marshes are an essential transition from the terrestrial environment to the coastal ocean (Bianchi, 2007). Not only do they provide a plethora of ecosystem services for humans and wetland organisms, but they are an important part of the global carbon cycle that affects both terrestrial and aquatic environments. Though not fully understood, it is believed that wetland ecosystems such as salt marshes contribute to the fate and storage of terrestrial and atmospheric carbon in the environment (Bauer et al., 2013). The ability of salt marshes and other shallow, coastal, vegetated ecosystems such as mangroves and seagrass beds to sequester carbon has been termed “blue carbon storage” and is of major focus in current climate change research (Osburn et al., 2015).

Carbon can be present in the environment as dissolved organic carbon (DOC) which, in addition to organic forms of nutrients such as dissolved organic nitrogen (DON) and phosphorus (DOP), can be formed by salt marsh plants and associated organisms via primary production and respiration. These dissolved compounds can then be released into the coastal ocean with daily changes in tide (Cai et al., 2000; Hedges, 1992; Winter et al., 1996). The dominant plant in North Carolina salt marshes is the smooth cordgrass Spartina alterniflora which has the ability to store and release large amounts of DOC, DON, and
DOP (collectively referred to as dissolved organic matter, DOM), and inorganic nutrients (as nitrate, NO$_3^-$, nitrite, NO$_2^-$, ammonium, NH$_4^+$, and orthophosphate, PO$_4^{3-}$). This storage and release occurs in vegetative aboveground shoots as well as in surrounding sediments (Turner, 1993; Bianchi, 2007).

The release of DOC, N, and P from plants such as _S. alterniflora_ and surrounding sediments is thought to be an important component of carbon and nutrient sources to the coastal ocean. This DOM can fuel secondary production, but there are complex processes that create uncertainty in how this can be experimentally quantified (Bauer _et al._, 2013; Childers _et al._, 1993; Dame _et al._, 1986). A theoretical exchange diagram is represented in Figure 1 which shows this complexity. Aside from biological or physical processes (e.g. tidal currents and waves) which may alter the composition of DOM in the environment, anthropogenic influences such as wetland destruction, wetland modification, nutrient inputs, and climate change are constantly altering the dynamics of the coastal carbon and nutrient cycles (Childers and Day, 1990; Koch and Gobler, 2009; Loomis and Craft, 2010). For instance, Koch and Gobler (2009) showed that in salt marshes that have been ditched for drainage purposes, NO$_3^-$ export was greater than that of intact salt marshes which were a sink for NO$_3^-$ and other nutrients.

It has also been shown that increased levels of carbon dioxide (CO$_2$) in the atmosphere, in addition to enhanced nutrient loading of coastal waters, may ultimately result in the production of more DOC by salt marsh organisms (Bauer _et al._, 2013; Marsh _et al._, 2005; Osburn _et al._, 2015). This reflects the importance of DOC and nutrient fluxes from wetlands like the _S. alterniflora_ salt marshes found so ubiquitously along the eastern coast of the United States. The latest report by the Intergovernmental Panel on Climate Change (IPCC) also supports the role of wetlands as a crucial reservoir for CO$_2$, and as a possible source or sink for DOC (Ciais _et al._, 2013).

According to Kirwan and Mudd (2012), half of all carbon burial occurs in shallow water ecosystems such as salt marshes. While increasing atmospheric CO$_2$ levels are expected to increase rates of salt marsh carbon sequestration and assimilation, rapid environmental changes due to climate change may lessen the effectiveness of these processes. Under normal rates of relative sea level rise (RSLR) and CO$_2$ abundance, salt marshes can respond by accreting more sediment and storing higher concentrations of organic matter within the sediment (Kathilankal _et al._, 2008). However, at current RSLR rates, marsh accretion cannot occur quickly enough, resulting in a flooded marsh with low sequestration capabilities (Kathilankal _et al._, 2008; Osburn _et al._, 2015). Thus, as shown in Kirwan and Mudd’s (2012) climate model, the positive feedback that is associated with CO$_2$ assimilation in salt marshes will eventually diminish. Furthermore, ways to accurately quantify carbon and nutrient dynamics are being researched to enhance the understanding of the capacity at which salt marshes influence DOM cycling.

One of the most well-known ideas regarding carbon and nutrient export in estuarine systems is the outwelling hypothesis. The hypothesis states that estuarine systems and associated aquatic influences such as riverine and tidal exchanges occur too quickly for significant utilization of organic matter by organisms to occur. Thus, estuaries simply act as exporters of these compounds, and there is virtually no biogeochemical activity (Odum, 1980 as cited in Hazeldon and Boorman, 1999). This has, however, been supported as well as challenged many times since its inception as technological advances and new techniques have given rise to a more accurate characterization of salt marsh DOC and nutrient fluxes.

For instance, Taylor and Allanson (1995) stated that the outwelling hypothesis is not universal and the heterogeneity of salt marshes is so extreme that areas such as high marsh habitats are not accurately considered. Different conclusions have also involved study sites that vary geologically,
Figure 1: Diagram showing the fate of DOM in estuarine environments and the relationship between sediments, the water column, and associated organisms (Adapted from Hansell and Carlson, 2002 as cited in Bianchi, 2007).
geographically, biologically, chemically, and physically. Murray and Spencer (1997) identified the need to incorporate tidal processes into flux calculations and overall budgets for tidal wetlands, further underscoring the complexity of quantifying and characterizing fluxes of compounds in salt marshes. Furthermore, it has been found that the source-sink dynamics of salt marshes depend on a variety of factors including marsh maturity, available tide energy, salinity, and balance between microbial loop processes (Figure 2; Childers et al., 1993; Dame et al., 1986; Hopkinson et al., 1999; Negrin et al., 2011; Tyler et al., 2003).

It has been suggested that sediments may be the primary source of DOM (as carbon and nitrogen) where microbial remineralization of highly refractory organic matter occurs (Burdige, 2002; Koch and Gobler, 2009). Observations have shown that DOM in pore waters is more highly concentrated than water column concentrations, further supporting the transfer of DOM from sediments to the above water column (Burdige, 2002; Childers and Day, 1990; Tyler et al., 2003). Some have suggested that abundant inorganic nitrogen imported to estuaries is quickly removed via denitrification processes before ebbing tides are able to carry it back to the coastal ocean, and that sedimentary processes cause salt marshes to be a sink for nitrogen (Cai et al., 2000; Dame et al., 1986; Osburn et al., 2015).

Maher and Eyre (2010) provide further evidence of sedimentary microbial remineralization and have suggested that DOC production is directly correlated with metabolic bacterial production, while others have cited remineralization processes as a driver of fixed nitrogen export (Anderson et al., 1997; Caffrey et al., 2007). The exact mechanism remains unknown, however, as there are seasonal variations and uncertainty as to how microbial communities are affected by the aforementioned complexities of salt

Figure 2: Simple schematic of the microbial loop and associated microorganisms responsible for remineralization of DOM (Adapted from Foreman and Covert, 2003 as cited in Bianchi, 2007).
marsh heterogeneity and associated physical, chemical, and geological effects. Seasonal comparative studies have shown that salt marshes uptake DOM in the winter while it is exported in the highest concentrations in the summer (Bouchard, 2007; Hopkinson et al., 1999; Osburn et al., 2015; Yelverton and Hackney, 1986). Variations in these findings exist, however, as Childers and Day (1990) and Dame et al. (1986) observed an uptake of DOC in summer with a release of DOC and DON in winter and spring. Besides these generalizations, many studies cited in this paper exhibit nuances that become easily apparent when compared. These nuances include differences in DOC and nutrient concentrations, fluxes, study sites, seasons, tides, duration of study, etc.

Thus, the objective of this particular project was to characterize in situ DOM (as DOC, DON and DOP) and inorganic nutrient fluxes from a temperate North Carolina S. alterniflora salt marsh during the summer and winter seasons. Average daily fluxes from vegetated and non-vegetated sediments were derived from in situ benthic chambers and compared between treatments and seasons. Ratios of C:N:P for fluxes were also calculated. We hypothesized that there would be no differences in sediment fluxes between vegetated and non-vegetated salt marsh sediments. However, vegetated sediments would exhibit greater flux magnitudes than non-vegetated sediments. In addition, we also hypothesized that summer fluxes would be greater than winter fluxes.

In relation to the methods that were used in this study, similar experimental procedures attempting to quantify DOM and nutrient fluxes in the region have included the laboratory incubation of S. alterniflora (Wang et al., 2014) and the leeching of S. alterniflora leaves in situ (Turner, 1993). In addition, Howes and Goehringer (1994) and Ketover (2011) used an in situ chamber microcosm method in order to characterize DOM and nutrient fluxes from salt marsh sediments and mangrove swamps, respectively. Also, while Neubauer and Anderson (2003) characterized dissolved inorganic carbon flux in salt marshes, the use of chamber microcosms focusing directly on the in situ release of DOM and nutrient fluxes from S. alterniflora salt marshes has not been attempted.

In order to constrain the current coastal carbon budget, it is important to quantify the amounts of DOM and inorganic nutrients exported to coastal waters and to determine how salt marshes are acting as sources or sinks of organic carbon (Bauer et al., 2013). In a broader sense, as CO₂ levels in the atmosphere increase contributing to global climate change, it is essential to know where this carbon is going.

**METHODS**

**Study Site.**

This study was conducted at the University of North Carolina Wilmington’s Center for Marine Science and the surrounding Spartina alterniflora salt marsh ecosystem that borders the Intracoastal Waterway (Figure 3). This particular marsh area is approximately 1.32 ha and experiences semidiurnal tides in which the marsh is inundated with seawater for roughly half of the day. The fringing experimental marsh is influenced by flooding and ebbing tidal processes. There were no freshwater influences for the duration of the experiment other than surface run-off. The study was conducted twice over the course of a year to account for the variable environmental conditions and ecosystem responses to temperature changes. The first was conducted in July 2015 to mimic summer sediment fluxes of DOM and nutrients, while the second experiment was conducted in December 2015 to mimic winter fluxes. Both field experiments followed the same procedures.

**Field Experiments.**

Field methods closely followed those of Neikirk (1996) and Ketover (2011). In situ microcosms were placed in the marsh during low tide. These microcosms were acrylic benthic chambers with a height of 61 cm
and an inner diameter of 30 cm (Figure 4). Each chamber contained two holes drilled 15 cm from the bottom which allowed them to be filled during a flooding tide. Chambers were driven into 10-15 cm of sediment a few days prior to the start of the experiment so disturbed sediment could settle within the chamber. Three of these chambers were placed over a patch of S. alterniflora and three chambers were placed over bare sediment without the influence of S. alterniflora. Hereafter, the chambers placed over a patch of S. alterniflora and over bare sediment will be referred to as vegetated and non-vegetated treatments, respectively.

The experiments were conducted in the morning at the beginning of the ebbing tide. Prior to the start of the experiments, the holes on the bottom of all the sediment chambers were plugged. In addition, one sealed control chamber filled with ambient seawater was placed in the marsh upon the start of the experiment. It should be noted that the data collected from the control chamber was subtracted from the data collected in the other six chambers to account for any microbial activity that may have occurred in the water column for the duration of the experiment.

Water samples from each chamber were collected after each was gently stirred for homogenous mixing to avoid anoxia. Samples were collected at the beginning of the experiment and every 45 minutes thereafter for a total of 270 minutes (T_0, T_45, T_90, ..., T_270). The first four samples were taken in natural light and the second three samples were taken in

Figure 3: Map of Wilmington, NC and surrounding features where field experiments were conducted. The black star indicates the location of the study site along the Atlantic Intracoastal Waterway. Image courtesy of Melissa Smith.
Figure 4: A model of the in situ chambers used in this experiment. The chambers were placed over vegetated and non-vegetated sediments. The control chamber, filled with ambient seawater, has a sealed bottom and does not have holes. Chamber design is modified from Neikirk (1996).

The dark by placing black trash bags over the chambers. This allowed for the quantification of daily changes (presence or absence of light) in DOM and inorganic nutrient fluxes. Each sample was immediately filtered through baked (500 °C for 4 h.), 0.7 μm glass-fiber filters (Whatman GF/F) into 50-mL acid-washed (10% hydrochloric acid, HCl), centrifuge tubes and frozen until analyses.

Temperature and dissolved oxygen concentrations were monitored using a YSI Water Quality Field Meter to ensure that they were stable throughout the experiment and the chambers did not undergo anoxia. Surface sediment samples corresponding to each sediment chamber were also collected and stored in baked (500 °C for 4 h.) glass jars and frozen until analyses. To account for any leakage from the chambers during the experiment, the volume of each chamber was noted and used as a correction factor when calculating flux values.
Sediment Analysis.

Collected sediment samples were analyzed for sedimentary organic C and N (SOC and SON, respectively) content using a ThermoQuest NC 2100 sediment analyzer (UNESCO, 1994). To prepare samples for SOC and SON analyses, thawed samples were dried to remove water, ground to a very fine particle size, and removed of large pieces of debris. Two subsamples of each were acidified with 10% TraceMetal Grade HCl to remove any carbonates. After again drying, each sample was weighed and packed into tin capsules for analysis.

Samples were analyzed in duplicates in which C and N amounts in each sample were given as a function of grams of dry sediment weight (gdw). Molar ratios of C:N were also calculated for each sample.

Nutrient Analysis.

Each water sample collected from the field was analyzed for DOC, dissolved inorganic nitrogen (DIN), dissolved organic nitrogen (DON), dissolved inorganic phosphorus (DIP), and dissolved organic phosphorus (DOP).

Concentrations of DOC were analyzed using a Shimadzu TOC-V high temperature combustion instrument following a modification of the Benner and Strom (1993) method (Loh and Bauer, 2000). Total dissolved nitrogen (TDN) and total dissolved phosphorus (TDP) concentrations were determined using a modification of the persulfate digestion method from Koroleff (1983). Samples were digested to nitrate (NO$_3^-$) or phosphate (PO$_4^{3-}$), respectively, and analyzed using a Bran+Luebbe AutoAnalyzer 3 (Loh, 2005).

Concentrations of DIN as NH$_4^+$ and NOx (the combined concentrations of nitrite, NO$_2^-$ and nitrate, NO$_3^-$) and DIP (PO$_4^{3-}$) were also determined using a Bran+Luebbe AutoAnalyzer 3 without the persulfate oxidation step. Subsequent concentrations of DON and DOP were calculated by subtracting the respective DIN and DIP concentrations from the measured TDN and TDP concentrations using the following equations (Koroleff, 1983):

\[ [\text{DON}] = [\text{TDN}] - [\text{DIN}] \] (Eq. 1)
\[ [\text{DOP}] = [\text{TDP}] - [\text{DIP}] \] (Eq. 2)

Flux Calculations.

Based on DOC and nutrient concentrations obtained over time, DOC and nutrient (organic and inorganic) fluxes were obtained by creating a linear regression of the concentrations measured over time. The slope of each regression was used to calculate flux by taking into consideration the volume and areas of the chambers. If the chambers experienced any sort of leakage during the experiment and therefore a change in volume, it was factored into the equation when determining final mean daily fluxes to ensure all data was consistent and normalized. The equation below represents the flux calculation:

\[ J = \frac{dC}{dt} \times \frac{V}{A} \] (Eq. 3)

where $J$ = flux, $dC/dt$ = slope of linear regression, $V$ = volume of chamber, and $A$ = area of chamber.

All concentration measurements were obtained in μmol L$^{-1}$ while daily flux calculations were expressed as μmol m$^{-2}$ d$^{-1}$ after factoring in the duration of the experiment compared to a full 24-h. day. Fluxes from the control chamber were then subtracted from the sediment chamber fluxes to correct for any microbial activity in the water column that was not being considered for this experiment. Lastly, C:N:P flux ratios for DOM and inorganic nutrients were calculated.

Statistical Analysis.

Multivariate Analysis of Variance (MANOVA) assuming unequal variance and non-normality according to Levene’s Test of Equality of Error Variances among the datasets was conducted using the SPSS statistical software to simultaneously observe any differences between vegetated and non-vegetated treatments and between summer and winter fluxes. Differences were determined
Sediment Data.

Sediment samples were analyzed for sedimentary organic carbon (SOC) and sedimentary organic nitrogen (SON) content and ratios of C:N calculated (Table 1). Vegetated sediments had SOC content ranging from 15.77 - 20.23 mg C/gdw, while SON content ranged from 0.5906 - 0.9457 mg N/gdw. Ratios of C:N of vegetated sedimentary organic matter ranged from 21.82:1 to 27.03:1. Non-vegetated sediments had SOC content ranging from 13.86 - 16.12 mg C/gdw, while SON content ranged from 0.5393 - 0.6420 mg N/gdw. There were no significant differences in SOC and SON content between seasons or between treatments within the same season. Ratios of C:N of vegetated sedimentary organic matter ranged from 26.72:1 to 29.00:1. There were significant differences (p < 0.01) in C:N ratios between July and December vegetated sediments but not between non-vegetated sediments or between different treatments within the same season.

DOC and Nutrient Fluxes.

Mean daily fluxes expressed in μmol m$^{-2}$ d$^{-1}$ for DOC and nutrients are shown in Figures 5-7. Positive flux values indicate that sediments are a source of DOM or nutrients while negative values indicate that sediments are a sink for DOM or nutrients. Data from one vegetated chamber in July was not factored into flux results due to major chamber leakage and inadequate sample retrieval during the field experiment.

### RESULTS

**Hydrographic Data.**

The summer experiment was conducted on July 17, 2015. In the field, air temperature was 31.1 °C, water temperature 28.7 °C, and salinity 35.97. The winter experiment was conducted on December 9, 2015. Air temperature was 15.6 °C, water temperature 15.0 °C, and salinity 33.0. Air and water temperature were typical for each season in which the experiment was conducted, and salinity remained stable at typical values for coastal waters. Additionally, dissolved oxygen (DO) content of the water in the chambers was monitored to ensure that the sampling column did not undergo anoxia. In both seasons, DO (mg/L) and DO (%) were normal and remained oxic throughout the experiment. The July experiment exhibited mean values of 4.82 ± 0.105 mg/L and 77.5 ± 1.91% while the December experiment exhibited mean values of 6.33 ± 0.102 mg/L and 72.8 ± 1.00%.

<table>
<thead>
<tr>
<th></th>
<th>July Vegetated</th>
<th>December Vegetated</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOC (mg/gdw)</td>
<td>20.23 ± 2.45</td>
<td>15.77 ± 2.09</td>
</tr>
<tr>
<td>SON (mg/gdw)</td>
<td>0.9457 ± 0.140</td>
<td>0.5906 ± 0.094</td>
</tr>
<tr>
<td>C:N</td>
<td>*21.82:1 ± 0.86</td>
<td>*27.03:1 ± 0.85</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>July Non-vegetated</th>
<th>December Non-vegetated</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOC (mg/gdw)</td>
<td>13.86 ± 1.69</td>
<td>16.12 ± 2.51</td>
</tr>
<tr>
<td>SON (mg/gdw)</td>
<td>0.5393 ± 0.131</td>
<td>0.6420 ± 0.140</td>
</tr>
<tr>
<td>C:N</td>
<td>29.00:1 ± 3.65</td>
<td>26.72:1 ± 2.91</td>
</tr>
</tbody>
</table>

Table 1: Mean C:N ratios and sedimentary organic carbon and nitrogen (SOC, SON) content are expressed as mg/gdw (with standard error) for each season and treatment. (*) indicates a significance level of p < 0.01.
Figure 5: Treatments (vegetated and non-vegetated sediments) are plotted as a function of mean daily flux (μmol m$^{-2}$ d$^{-1}$) of DOC from three replicates of each treatment. Positive values indicate a DOC source while negative values indicate a DOC sink for a) summer and b) winter experiments. Standard error (SE) is not plotted as error bars due to variability in field data. Asterisks represent significance between seasons (p < 0.05).
Figure 6: Nutrients are plotted as a function of mean daily flux (μmol m$^{-2}$ d$^{-1}$) from three replicates of vegetated sediment chambers. Positive values indicate a nutrient source while negative values indicate a nutrient sink for a) summer and b) winter experiments. Bars represent one standard error (+1SE).
Figure 7: Nutrients are plotted as a function of mean daily flux $\mu$mol m$^{-2}$ d$^{-1}$) from three replicates of non-vegetated sediment chambers. Positive values indicate a nutrient source while negative values indicate a nutrient sink for a) summer and b) winter experiments. Bars represent one standard error (+1SE), and letters represent significance between seasons ($p < 0.05$).
For DOC fluxes, there were no significant differences in fluxes between treatments (vegetated vs. non-vegetated) within the same season (Figure 5). However, there was a significant difference (p < 0.05) in non-vegetated DOC fluxes between the July and December experiments. Vegetated sediments were a minor sink of DOC and non-vegetated sediments were a very minor source of DOC in July while in December both vegetated and non-vegetated sediments were a sink for DOC (Figure 5). Additionally, fluxes occurred with greater magnitude in December compared to July (>400 μmol m⁻² d⁻¹ vs. <100 μmol m⁻² d⁻¹).

For nutrient fluxes, a similar pattern was revealed in that there were no significant differences between treatments (vegetated vs. non-vegetated) within the same season (Figures 6-7). In addition, there were also no significant differences in organic or inorganic nutrient fluxes between seasons in vegetated sediments (Figure 6). However, in non-vegetated sediments, significant differences (p < 0.05) were found for NO₃ and DIN fluxes between seasons (Figure 7).

In vegetated sediments in July, there were positive fluxes of NO₃, NH₄⁺, and DIP (Figure 6) suggesting that the vegetated salt marsh sediments were a source of these nutrients. Vegetated sediments were also a sink for DON and DOP in July while in December, sediments were a sink for all measured components. July exhibited a greater magnitude of nutrient fluxes than in December. In non-vegetated sediments in July, sediments were a source of all nutrients including DON and DOP (Figure 7). In December, sediments were a sink for all components with magnitude of fluxes were greater than in July.

When inorganic and organic sediment flux ratios were calculated for C:N, C:P, and N:P ratios, there were no significant differences found between seasons and treatments. The highest values were found in DOC:DOP ratios, followed by DOC:DON, DON:DOP, and DIN:DIP (Table 2).

### DISCUSSION

The purpose of this experiment was to characterize in situ DOC and nutrient fluxes from vegetated and non-vegetated sediments in a *Spartina alterniflora* salt marsh under two distinct seasonal conditions and to determine any differences in sediment fluxes and magnitude between treatments (vegetated versus non-vegetated sediments) and between seasons (July versus December). It was initially hypothesized that there would be no differences in sediment fluxes between treatments (i.e., between sediments that were vegetated with *S. alterniflora* and those which were bare sediment without any vegetation) within the same season (Figures 5-7). The insignificance of fluxes between treatments may indicate that most of the biogeochemical cycling that occurs in salt marshes does so in the sediments which is consistent with previous conclusions (Anderson *et al.*, 1997; Burdige, 2002; Caffrey *et al.*, 2007; Cai *et al.*, 2000; Tyler *et al.*, 2003). It also appears that much of the remineralization could be

<table>
<thead>
<tr>
<th>Treatment</th>
<th>DOC:DON</th>
<th>DOC:DOP</th>
<th>DON:DOP</th>
<th>DIN:DIP</th>
</tr>
</thead>
<tbody>
<tr>
<td>July Vegetated</td>
<td>12.09</td>
<td>160.81</td>
<td>23.55</td>
<td>25.52</td>
</tr>
<tr>
<td>July Non-vegetated</td>
<td>199.61</td>
<td>1614.88</td>
<td>8.44</td>
<td>6.08</td>
</tr>
<tr>
<td>December Vegetated</td>
<td>21.40</td>
<td>1010.60</td>
<td>67.72</td>
<td>13.71</td>
</tr>
<tr>
<td>December Non-vegetated</td>
<td>30.60</td>
<td>3597.02</td>
<td>97.49</td>
<td>15.85</td>
</tr>
</tbody>
</table>

**Table 2:** Mean flux ratios for each season and treatment. There were no significant differences between flux ratios.
occurring in pore waters which may host a community of microbes that actively use DOM for metabolic processes (Cai et al., 2000). Additionally, this experiment did not analyze for grain size which could also impact pore water dynamics and therefore microbial loop processes and flux rate in or out of the sediment.

Conversely, while there were no differences present between seasons within vegetated sediments, fluxes greatly differed between July and December in non-vegetated sediments (Figure 7). It can be generalized that in July, salt marshes are a source for DOC, N, and P in non-vegetated sediments, while the vegetated sediments are a sink for DOC, N, and P compared with December where the entire marsh is a sink of DOC, N, and P. These results suggest that in December, microbial activity in the sediment is intensified, and DOM is being actively remineralized (Bianchi, 2007; Burdige, 2002; Cai et al., 2000; Dame et al., 1986; Hopkinson et al., 1999). These processes are dominated by N remineralization as seen in the significant differences in NOx and DIN fluxes between July and December non-vegetated sediments.

In addition to the disparity in sinks and sources for DOM and nutrients, the magnitude of fluxes also differed. In addition to December being a sink for DOC and nutrients, there was a larger magnitude of fluxes during this experiment. It is apparent that salt marsh sediments are capable of taking up large amounts of DOM in the winter, an observation that is important when considering blue carbon research. If salt marsh sediments are able to store large amounts of DOM in such a small area, it raises the question of how impactful large salt marsh areas may be in biogeochemical activity and therefore how influential it is to the coastal ocean which is so vital to ecosystem health. It seems that nutrients can be effectively contained in salt marshes and perhaps facilitate greater DOC production as supported by studies within Bauer et al. (2013), Cai et al., (2000), Koch and Gobler (2009), Loomis and Craft (2010), Osburn et al., (2015) and Turner (1993). One common idea is that salt marshes actively “filter” or control nutrient concentrations especially when considering anthropogenic inputs and stability of the coastal ocean. At a global scale, these results may also support the idea of CO2 sequestration in salt marshes as is consistent with additional insights from Anderson et al. (1997), Caffrey et al. (2007), Duarte et al. (2005), Kirwan and Mudd (2012), and Kathilankal et al. (2008).

Initially, the observed small P flux values may also suggest that the biogeochemical potential of salt marsh ecosystems are limited by P availability (Figures 6-7). However, the high negative flux of DON indicates a strong utilization by the microbial community even in July vegetated sediments when most other components exhibited positive fluxes (Figure 6). Under further investigation, ratios of N:P (Table 2) are relatively low, and even though N is utilized most often, it may also be the limiting nutrient due to the utilization of inorganic N in addition to organic N. In a similar system used in Anderson et al.’s (1997) study, results are consistent except in the case of high N loading circumstances.

As to issues regarding the experimental procedure, there were few instances where the benthic chambers in the field leaked. This was due to natural seepage from underneath the sediments. However, this volume change was corrected when fluxes were calculated. Additionally, every attempt was made to ensure that experimental patches were removed of all visible organisms such as snails, oysters, and algae. However, it is possible that unseen epifaunal or infaunal organisms were not removed which could also have some influence on the cycling of DOM. In addition, this study was conducted at a relatively small site where anthropogenic disturbances such as foot traffic and experimental equipment are evident. This could potentially influence the results in that pristine and vast areas of salt marshes may produce different results. However, it can be argued that the disrupted and fragmented nature of the salt marsh is representative of salt marshes currently undergoing anthropogenic stresses such as
encroachment. Additionally, Hopkinson and Vallino (1995) and van Heemst et al. (2000) suggest that human-derived particulate and dissolved carbon can impact the lability of organic matter in estuaries. That is, remineralization processes may involve the metabolism of nutritionally different carbon sources and the ability of microbial communities to utilize those compounds.

Ultimately, the results of this experiment are a good indicator that salt marsh biogeochemistry is much more complex than what was first described by Odum in 1980 and further supports studies citing microbial influences on salt marsh cycling (Anderson et al., 1997; Burdige, 2002; Caffrey et al. 2007; Cai et al., 2000; Maher and Eyre, 2010; Tyler et al., 2003). The readily produced and available DOC in salt marshes may fuel the microbial activity and consequent release of remineralized DOM in salt marsh sediments and provide a big picture approach to salt marsh biogeochemistry and how fluxes of DOC and nutrients can vary seasonally. The biogeochemical activity of these systems was shown to be complex and driven by microbial activity in the sediment further supporting the claim that salt marshes are among the most biogeochemically active ecosystems on Earth.

**CONCLUSION**

This research endeavor has resulted in many unanswered questions about sediment fluxes in *Spartina alterniflora* salt marshes. The information that was gained from this experiment in support of salt marshes acting as biogeochemical reactors as well as a source of DOC and nutrients to the coastal ocean has many implications. First, it adds to the understanding of how salt marshes operate in addition to the complex microbial processes that occur within sediments.

Future research in this area could focus much more on the microbial community that exists in the salt marsh sediments, particularly in pore waters, and the community composition that is responsible for remineralizing nutrients in the system. In relation, the heterogeneity of salt marsh ecosystems may result in vegetation types that differ with changes in elevation or distance from the shoreline. Of course, this experiment was limited by time and by space. Higher marsh habitats may exhibit different flux properties as well as those marshes with freshwater influences. So, while the general theory of biogeochemical reactivity and source-sink dynamics is supported, it would be difficult to use these fluxes to generate any sort of budget for salt marsh export.

In the future, a more comprehensive study should consider more of the microbial processes at work in the sediment to better understand the remineralization and microbial loop processes that operate to essentially suck up nutrients in the winter. Additional efforts should also be made to understand the effects of these processes on the coastal ocean. How might the biogeochemical activity of salt marshes affect water quality or other parameters in tidally influenced estuaries and coasts? This information could be vital to understanding the importance of salt marshes to coastal systems as valuable biogeochemical reactors.
REFERENCES


Age And Growth Of The Invasive Lionfish: North Carolina, USA, vs Bonaire, Dutch Caribbean

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Faculty Mentor: Thomas Lankford
University of North Carolina Wilmington

ABSTRACT
Lionfish are an invasive species that are now well established throughout the Atlantic. Originally from the Indo-Pacific, they have decimated local fishes’ populations due to their rapid reproduction, broad environmental tolerance, voracious appetite, and lack of predators. Through the examination of otoliths paired with morphometric data, this study investigates the age and growth of lionfish (sp. P. volitans) from two locations: North Carolina, USA and Bonaire, Dutch Caribbean. Otoliths were extracted from lionfish samples, embedded in resin, and then sectioned so that age could be determined with microscopic analysis. These age estimates along with the corresponding total lengths were used to calculate growth rates via the von Bertalanffy growth equation. Results returned a K and L-infinity value of 0.32 cm and 42.5 cm for lionfish from NC and 0.39 cm and 38.7 cm for Bonaire, respectively. These findings suggest that lionfish from NC have slower growth but grow older and larger than that of lionfish from Bonaire. This likely attributes to location as well as convenience and strength of removal efforts. In Bonaire, lionfish are hunted often and are easily accessible to the public, whereas in North Carolina, lionfish are found miles off the coast and their harvesting is not as popular.

Lionfish are an invasive species deriving from the Indo-Pacific that have now come to thrive in the Atlantic and Caribbean. Invasive lionfish can be classified into two species, the fire devil fish (P. miles) and red lionfish, (P. volitans). Both species look and behave very similar; they both appear to have red and white zebra-like stripes, long pectoral fins, venomous spines, and a sedentary, fearless demeanor (Schultz 1986). However, meristic counts differ between the species. P. miles generally has 10 dorsal-fin rays and 6 anal-fin rays while P. volitans usually has 11 dorsal-fin rays and 7 anal-fin rays (Schultz 1986). Also, Species P. volitans has a wider geographic invasive range than P. miles (Schofield 2009). This study focuses on species P. volitans.

The earliest sighting of lionfish in the Atlantic dates to 1985 off the southeastern coast of Florida and thought to be caused by negligent aquarists. Through mitochondria DNA analysis, this was shown to be likely source of the invasive (Freshwater et al. 2009). In 2000, multiple individuals were sighted off North Carolina and the surrounding states; nine years later, in 2009, lionfish were seen in Bonaire (de León et al. 2013). Presently, lionfish have been found as far south as Brazil and as far north as New York (Morris and Whitfield 2009, Freshwater et al. 2009, Green et al. 2012, Ferreira et al. 2009).
Lionfish are expected to continue invading the remainder of the Caribbean and to continue southward along the coast of South America until the water temperatures fall below their thermal tolerance limit (Morris and Whitfield 2009). Lionfish are classified as generalist carnivores that feed on a wide variety of fishes and crustaceans (Morris and Akins 2009). Lionfish consume prey at high rates, largely during crepuscular periods (Green et al. 2012). Their hunting strategy is unique among predatory fishes within the Caribbean. Lionfish hover motionless over prey with their large pectoral fins extended and are able to approach their prey closely before making a rapid strike. They also can extrude water jets to orient the prey towards the mouth before striking (Albins and Lyons 2012). Their relentless predation wreaks havoc on communities. For example, a 79% reduction in fish recruitment on experimental patch reefs in the Bahamas was observed during a five-week observation period in the presence of a single small lionfish (Albins and Hixon 2008). Another study reported lionfish prey biomass reduced by an average of 65% over a two-year-period (Green et al. 2012). This mass predation is cause for concern as the over-consumption of herbivore fishes can shift ecosystems to algae dominated coral as shown by Lesser and Slattery (2011). These shifts can effect both habitat and economy as seen during the mass extinction of the sea urchin, Diadema antillarum in the 1980’s (Mumby et al. 2006).

Lionfish are extremely tolerant and adaptive. They have been reported from all major marine seafloor and substrate types within the invaded Atlantic, and they occupy a range of depths (Morris et al 2009). They have no known predators and a proven voracious appetite; this paired with their ability to reproduce every 4 days drives their success (Morris et al 2009). Through the analysis of otoliths and recorded total lengths, this study aims to (1) produce von Bertalanffy growth curves and (2) investigate the age structure and growth with regards to environmental influences for two very different locations: North Carolina, USA and Bonaire, Dutch Caribbean.

METHODS

Lionfish samples were obtained from both locations during the summer of 2015 (June – August) (Figure 1). In North Carolina, 21 lionfish were purchased from local fishermen after their returns from the Onslow Bay area. In Bonaire, 17 lionfish were speared and donated by locals. Bonaire samples all were from the west coast of the island. However, due to human or experimental error, only 13 otoliths from each location were able to be completely evaluated.

For all samples collected, the species was verified, total length (TL) recorded, and the sagittal otoliths were extracted. Otoliths are small bones that are found within fishes’ craniums that help facilitate balance, orientation, and sound (Secor et al. 1991). As these bones grow, they form annual rings similar to like rings of a tree. These annuli can be counted to give age estimates and used in further calculations to produce growth curves (Secor et al. 1991). The otoliths were embedded in resin, mounted, and sectioned with an Isomet™ Low Speed Saw as following protocol from the Manual for Otolith Removal and Preparation for Microstructural Examination (Secor et al. 1991). Sections were then analyzed for annuli under a compound microscope to determine age. Further analysis for growth was conducted following protocol set forth by the FAO’s (Food and Agriculture Organization of the United Nations) manual, Introduction to Tropical Fish Stock Assessment (Sparre and Venema 1998).

The age estimates from the otolith analyses along with the corresponding total lengths were used to calculate a growth rate via the von Bertalanffy growth equation (Table 1.):

\[ L_t = L_\infty (1 - e^{-K(t-t_0)}) \]

where \( l(t) \) is length at time, \( t(0) \) is the...
Figure 1. Map of study area
Table 1. Raw otolith and corresponding age data for samples from North Carolina and Bonaire

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Total Length (cm)</th>
<th>Age (years)</th>
<th>Total Length (cm)</th>
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<td>0.6</td>
<td>15</td>
<td>0.1</td>
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<tr>
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<td>6</td>
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<td>43</td>
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Table 2. Comparison between parameters of von Bertalanffy growth equation for North Carolina and Bonaire

<table>
<thead>
<tr>
<th>Parameters</th>
<th>North Carolina</th>
<th>Bonaire</th>
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<tbody>
<tr>
<td>$L_\infty$</td>
<td>42.5 cm</td>
<td>38.7 cm</td>
</tr>
<tr>
<td>$K$</td>
<td>0.32 cm per year</td>
<td>0.39 cm per year</td>
</tr>
<tr>
<td>$T(0)$</td>
<td>-0.85</td>
<td>0.048</td>
</tr>
</tbody>
</table>

Table 1. Raw otolith and corresponding age data for samples from North Carolina and Bonaire

Table 2. Comparison between parameters of von Bertalanffy growth equation for North Carolina and Bonaire
theoretical length at age 0, K is the growth rate and L∞, termed ‘L infinity’ in fisheries science, is the asymptotic length at which growth is zero (von Bertalanffy 1934). This equation assumes that body length is a function of age. Parameters for this equation were calculated by the Ford-Walford plot. This plot graphs a fish’s length at year (t+1) against the fish’s length the previous year (t) producing the equation:

\[ L_{t+1} = L_\infty \left(1 - e^{-K}\right) + L_t e^{-K} \]

From this, the following parameters can be calculated from the linear regression via:

\[ L_{t+1} = a + b \cdot L_t \]
\[ K = -\ln(b) \]
\[ L_\infty = a / (1-b) \]

RESULTS AND DISCUSSION

Results return a K and L-infinity value of 0.32 cm and 42.5 cm for lionfish from NC and 0.39 cm and 38.7 cm for Bonaire, respectively (Table 2 and Figure 2). The age range of lionfish found in North Carolina was 0.6-6.0 years old with an average age of 2 years old (Figure 3). Bonaire lionfish showed a range of 0.1-5.0 years old with an average

Figure 2. Von Bertalanffy growth curves calculated from lionfish samples for both North Carolina and Bonaire
117°C (84°F). These warmer temperatures increase metabolic efforts which in turn affects growth (Thresher et al. 2007). The age structure seen in Figure 3 is likely attributed to other environmental influences such as location and accessibility. Bonaire is a small island renowned for its convenience for pristine diving. Local efforts to eliminate lionfish and help protect and conserve Bonaire’s reefs are strong. Government organizations (STINAPA), educational institutes (CIEE Research Station Bonaire), local dive shops, and visitors work closely together reporting and monitoring lionfish sightings to each other. These sightings are uploaded online to a ‘lionfish database’ that is open to the public. One can even go on to take a lionfish spearing course and after completion of the course receive a ‘lionfish license’, allowing them join the removal force. While these efforts target all lionfish, typically older, larger fish are the first to be removed affecting overall age structure. These types of collaborations and removal efforts have proven effective in reducing lionfish abundance (Ali 2015, Ali et

age of 1 year (Figure 3).

These results are similar to those found in past studies from the Western Atlantic and Caribbean. One study from the Cayman Islands reported lionfish with a K growth rate of 0.42 and a $L_\infty$ value of 34.9 cm (Edwards et al. 2014) while another from Onslow Bay, NC reported lionfish with a K growth rate of 0.32 and a $L_\infty$ value of 45.5 cm (Potts et al. 2010). While the von Bertalanffy growth function (VBGF) is widely accepted, the assumptions and limitations should be recognized (Pardo et al. 2013). The VBGF is was not adjusted for seasonality which could produce variations in the growth coefficient. Additionally, bias in K has been shown based on the variation between using the calculated value of the length at age zero parameter, t(0), versus observed values (Pardo et al. 2013).

North Carolina lionfish appeared to be older and larger than Bonaire lionfish. However, Bonaire lionfish showed a slightly faster growth rate. This could be influenced by climate and temperature. Bonaire’s year-round monthly average temperature is ~29°C (84°F). These warmer temperatures increase metabolic efforts which in turn affects growth (Thresher et al. 2007). The age structure seen in Figure 3 is likely attributed to other environmental influences such as location and accessibility. Bonaire is a small island renowned for its convenience for pristine diving. Local efforts to eliminate lionfish and help protect and conserve Bonaire’s reefs are strong. Government organizations (STINAPA), educational institutes (CIEE Research Station Bonaire), local dive shops, and visitors work closely together reporting and monitoring lionfish sightings to each other. These sightings are uploaded online to a ‘lionfish database’ that is open to the public. One can even go on to take a lionfish spearing course and after completion of the course receive a ‘lionfish license’, allowing them join the removal force. While these efforts target all lionfish, typically older, larger fish are the first to be removed affecting overall age structure. These types of collaborations and removal efforts have proven effective in reducing lionfish abundance (Ali 2015, Ali et

Figure 3. Age structure of lionfish samples from Bonaire and North Carolina

Samantha Farquhar
The role of volunteers and group effort is described as essential as increased removal effort has both decreased lionfish and allowed researchers to collect a large sample size in a short time to collect further data (Ali 2015, Ali et al. 2013). Moreover, a study that compared fished and unfished areas of Bonaire over a two year period (2009-2011) found that lionfish biomass in fished locations on Bonaire was 2.76-fold lower than in unfished areas on the same island (de León et al. 2013).

Additionally, the culling of lionfish is not just beneficial for the environment; it has been shown to be tasty and nutritious as well. The fish is described to have a “delicate flakey white meat” and shown to have a high omega-3 content (Morris et al., 2011). Thus, it is not uncommon to see lionfish on the menu in restaurants or markets throughout the Caribbean.

As discussed, in Bonaire, lionfish are hunted often and are easily accessible to the public. However, in North Carolina, this is not the case. Lionfish are found miles off the coast and in much deeper water (~40 m). Most importantly, their removal is not as popular. There are some lionfish derbies that have proven successful in the area as well as educational outreach, but these removal efforts are not as consistent as that of Bonaire.

Recent surveys from 2010 have shown that lionfish densities in Onslow Bay were as high as 200 lionfish per hectare (Whitfield et al. 2014). Thus, this number will likely increase unless a balance is found within the ecosystem or their removal and harvesting gains popularity.

This study has implications for management, tracking and monitoring, and planning of the lionfish invasion. The produced von Bertalanffy growth curves (Figure 2) allow for an estimate of age based only on the total length measurement of a fish. This can save future researchers the cumbersome task of otolith extraction and analysis. While the accessibility of lionfish cannot be changed in North Carolina, other aspects from Bonaire’s successful removal effort could be adapted for North Carolina. Outreach education programs and removal efforts can be increased. Restaurants and markets alike could be encouraged to offer lionfish. Additionally, a lionfish database to which reported sightings can easily be uploaded would prove beneficial.
REFERENCES


Caffeine’s Effects On Skeletal Muscle Bioenergetics In Vitro

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Faculty Mentor: Stephen Kinsey
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ABSTRACT
The purpose of this investigation was to study the effects of caffeine on respiration rate and utilization of glucose, glutamine, and fatty acids in C2C12 mouse skeletal muscle cells. Treatment of cultured C2C12 cells with 1 mM caffeine for 24 hours significantly (p<0.05) decreased the basal and maximal oxygen consumption rate (OCR), and therefore respiratory capacity when compared to controls. In addition, caffeine decreased the extra-cellular acidification rate (ECAR), indicating a reduction in the rate of anaerobic glycolysis. Measurement of OCR through the use of a metabolic assay analyzer also revealed a significant (p<0.05) decrease in glucose oxidation and fatty acid oxidation in response to caffeine. However, caffeine induced an increase in fatty acid oxidation as a percentage of total fuel usage. The reduction in OCR and ECAR following caffeine treatment suggests that this drug likely inhibits ATP turnover or induces programmed cell death in C2C12 muscle cells.

Caffeine is the most widely used drug in the western world (Graham, 2001). Approximately 75% of consumed caffeine comes in the form of coffee and this precious liquid is second only to oil in dollar amount traded annually (Keisler and Armsey, 2006). Once ingested, caffeine is rapidly absorbed in the gastrointestinal tract (Blanchard and Sawyers, 1983) and disseminated throughout the entire body (Axelrod and Reisenthal, 1953), and it is known to cause numerous physiological and neurological effects (Ritchie et al., 2007, Davis et al., 2002, Bell et al., 1998, Daniels et al., 1998). Caffeine has been used to enhance athletic performance since the 1920s (Jacobson and Kulling, 1989) and it is an exceedingly popular mental stimulant (Wesensten et al., 2005). However, the cellular ramifications of chronic caffeine use remain ambiguous, even though use of caffeine is approaching record highs (Keisler and Armsey, 2006, Spriet, 1995).

The effects caffeine imposes on those who ingest it are intimately tied to cellular respiration (Bracco et al., 1995, Robertson et al., 1978). During cellular respiration, oxygen, and fuel molecules such as fatty acids, glucose, and glutamine are consumed by mitochondria to produce adenosine triphosphate (ATP)—the cellular unit of energy (Aschenbach et al. 2002). If nutrient availability is not a limiting factor, cells that process oxygen at higher rates can produce more ATP. For example, the primary limiting factor during exercise is the rate at which muscle cells consume oxygen to meet the body’s elevated energy (Bassett and Howley, 2000). When energy demand is not met by aerobic respiration, anaerobic fermentation supplies the required ATP, but it is less efficient at making ATP and also produces lactic acid as a byproduct (McArdle et al. 2010). Lactic acid production from the anaerobic process of glycolysis acidifies the interior of the cells and releases free H+ ions into the extracellular fluid (Owicki and Parce, 1992).
Glycolytic activity can therefore be measured by observing alterations in the $\text{H}^+$ ion concentration in the extracellular fluid immediately surrounding cells (Lardner, 2000). Together, measurement of the oxygen consumption rate (OCR) and the extracellular acidification rate (ECAR) provides a useful indicator of the bioenergetics status of skeletal muscle cells (Wu et al. 2007). Therefore, this work employed a measurement technique to evaluate the effect of caffeine on aerobic and anaerobic metabolism in C2C12 cells.

Caffeine has been found to influence OCR and metabolism (Bauer et al. 2001). Long-term administration of caffeine in preterm infants is associated with an increase in oxygen consumption. Another study conducted by Chad and Quigley (1989) saw oxygen consumption and metabolic rate in female subjects increase significantly 1 hour after caffeine ingestion. Caffeine has also been shown to activate the AMP activated protein kinase (AMPK), which in turn leads to mitochondrial biogenesis, and therefore an increase in cell metabolic rate (Mathew et al., 2014). Additionally, skeletal muscle mitochondria primarily oxidize three key fuels: long chain fatty acids, glucose, and glutamine (Kelley and Mandarino, 2000). There is evidence that caffeine alters substrate utilization (Raney and Turcotte, 2008, Arciero et al., 1995). Inhibition of these fuels yields changes in respiration and therefore differences between these changes observed in cells treated and untreated with caffeine provide data on how caffeine affects oxidation of key metabolic fuels.

The present study evaluated the effects of caffeine exposure on the bioenergetic status of C2C12 skeletal muscle cells. We tested the hypotheses that 24 h of 1 mM caffeine treatment would increase the overall rate of respiration in C2C12 cells, due to its stimulatory effects on certain cell types, and that caffeine treatment would increase use of glucose as a metabolic fuel over fatty acids and glutamine. The widespread use of caffeine, including among children whose muscles are still developing, make understanding its effects on muscle metabolism an important public health issue.

METHODS

Cell Culture

C2C12 mouse skeletal muscle cells (myoblasts) were acquired from ATCC (ATCC CRL-1772, Manassas, VA, USA). Cells were grown at 37 °C in 5% $\text{CO}_2$ and cultured under sterile conditions in growth medium [Dulbecco’s modified Eagle’s medium (DMEM) with 10% fetal bovine serum, penicillin/streptomycin]. Proliferation of the cells was monitored using a tissue culture light microscope to determine confluence. To permit passage of cells between containers, adherent cells were dissociated from the vessel in which they were cultured using the proteolytic enzyme trypsin.

Bioenergetic Assay

Oxygen Consumption Rate and Extracellular Acidification Rate

C2C12 myoblasts were plated on XFp microplates (Seahorse Bioscience, North Billerica, MA, USA) at a density of 10,000 cells/well in growth medium and cultured at 37 °C in 5% $\text{CO}_2$. Cells reached ~90% confluence after 1 day, at which time growth media was removed and replaced with differentiation media (DMEM with 2% horse serum). After 5 days of serum restriction, multinucleated myotubes formed and were ready for treatment. Fresh media was administered every 24 hours. To determine the mitochondrial and glycolytic function in C2C12 muscle cells, a cell mitochondrial stress assay was conducted using a Seahorse XFp Extracellular Metabolic Flux Analyzer. After myocytes had differentiated 5 days, cells were treated with 1 mM caffeine in differentiation media for 24 hours. After 21 hours of the incubation period, cell media was replaced with non-bicarbonate, pH 7.4 assay media (XF Assay Medium, Seahorse Bioscience), supplemented with 25 mM glucose, and 4 mM sodium pyruvate, and incubated for the final 3 hours in a non-$\text{CO}_2$
incubator. The same media was used as vehicle for the compounds that were injected as part of the assays. The XFp Analyzer was then used to measure the cell oxygen consumption rate (OCR) in pmol O$_2$/min and extracellular acidification rate (ECAR) in mpH/min. OCR and ECAR values measure rates of mitochondrial respiration and glycolytic activity, respectively.

Two types of assays were run to analyze OCR and ECAR data from skeletal muscle cells: the Mitochondrial Stress assay and Mitochondrial Fuel Flex assay (Seahorse Biosciences). In the case of the Mitochondrial Stress assay, the XFp analyzer sequentially injected the following compounds into the assay medium: oligomycin (1 µM final concentration), which blocks the ATP synthase and shows the OCR dedicated to ATP production; carbonyl cyanide 4-(trifluoromethoxy) phenylhydrazone (FCCP: 4 µM final concentration), which permeabilizes the inner mitochondrial membrane and shows maximal OCR; and rotenone/antimycin A (1 µM final concentration for each), which blocks complex I and III showing non-mitochondrial OCR. Each assay used one Seahorse Bioscience 8-well microplate; 3 wells for each of the two treatment groups (control and 1 mM caffeine), and 2 calibration control wells that contain only assay media. Two plates of cells were analyzed for each parameter that was tested (n=6). OCR and ECAR were measured at three time points during basal respiration and after each drug injection.

**Metabolic Fuel Utilization**

The second assay type conducted was the Mitochondrial Fuel Flex assay and can be described as follows. The analyzer sequentially injected mixtures of the following compounds into the assay medium: UK5099 (2 µM final concentration), which inhibits the mitochondrial pyruvate carrier and thus the glucose oxidation pathway; BPTES (3 µM final concentration), which inhibits the enzyme glutaminase, subsequently preventing oxidation of glutamine, and etomoxir (4 µM final concentration), which inhibits carnitine palmitoyl-transferase 1A, an essential enzyme for translocating long chain fatty acids from cytosol into mitochondria for oxidation, which therefore inhibits long chain fatty acid oxidation. By selectively inhibiting the oxidation of glucose, glutamine or fatty acids while measuring the OCR, the contribution of each fuel to total OCR of cells can be determined. Therefore, one can measure the effects of caffeine treatment on cellular fuel preference. Just as with the Cell Mitochondrial Stress assay, there were 3 wells per treatment group (control and 1 mM caffeine), and three plates were used per experiment (n=9).

**Data Analysis**

All data were entered into Microsoft Excel, which was used to produce graphs and calculate mean values for OCR and ECAR. Results are reported as means ± SE. Data were analyzed using ANOVA and paired t-test in JMP Pro 12. Statistical significance was determined if p < 0.05.

**RESULTS**

**Effect of Caffeine on Mitochondrial OCR**

The effects of caffeine on skeletal muscle OCR and ECAR during a mitochondrial stress assay are shown in Figure 1. There was a significantly (p<0.05) lower mean OCR initially (basal OCR) and after addition of FCCP (maximal OCR) (Figure 1A). A summary of the data collected for OCR is presented in Figure 2, where every measure of mitochondrial function had a lower mean value in the caffeine treated cells than in the control. However, only the basal and maximal OCR and the aerobic scope (difference between maximal OCR and basal OCR) were significantly (p<0.05) lower in the caffeine treated cells. Similarly, mean ECAR was noticeably lower in the caffeine treated cells where every measurement reflected a lower mean value (Figure 1B). However, only the ECAR measured immediately after FCCP addition was significantly (p<0.05) lower in
Effects of Caffeine on Metabolic Fuel Utilization

To understand caffeine’s effects on fuel utilization of the three major energy sources for skeletal muscle cells (glucose, glutamine, fatty acids) the OCR was measured while sequentially inhibiting each fuel. The subsequent drop in OCR following inhibition of a particular fuel is indicative of the energy obtained from oxidizing that fuel in respiration. The subsequent addition of inhibitors of the other two fuel sources caused an additional drop in OCR, and the total decrease in OCR can be used to calculate the percent contribution of each fuel to basal OCR. OCR measurements during addition of inhibitors for each fuel is shown in Figure 3, and a summary of the data for each fuel is shown in Figure 4. There was a significant (p<0.05) reduction in utilization of glucose and fatty acids in the caffeine treated cells, and mean glutamine utilization also was lower in the caffeine treated group, although not significantly (p>0.10) so (Figure 4A). The percent contribution of glucose to total fuel utilization was lower in caffeine treated cells, while fatty acid oxidation represented a significantly (p<0.05) larger contribution to total fuel use after caffeine treatment (Figure 4B). Together, the collected data showed that fatty acids were the most substantial source of cellular energy, followed by glutamine, with glucose as the least employed source of cellular energy among the three examined fuels. Caffeine caused a relative increase in dependence on fatty acids.

DISCUSSION

Effect of Caffeine on Mitochondrial OCR

Basal oxygen consumption rate in C2C12 myocytes treated with caffeine was significantly lower than that of the untreated control muscle. Caffeine’s ability to decrease calcium (Ca²⁺) sequestering by the endoplasmic reticulum (ER) (Krizaj et al., 1999, Blinks et al., 1972, Smits et al., 1985, Schoppe et al., 1997) may have had an effect on the observed decrease in mitochondrial OCR. Excessive Ca²⁺ release and increase in cytosolic Ca²⁺ causes ER stress and could have led to the decreased OCR observed (Mekahli et al., 2011). Additionally, all OCR measurements for caffeine-treated cells exhibited lower OCR than the control, which points toward two likely conclusions. The first is that caffeine imposes a direct effect on cellular energy needs in C2C12 cells. This could have occurred by directly affecting mitochondrial function. Caffeine has been shown to hinder mitochondrial capacity to recover membrane potential (Sardão et al., 2002) and the existence of concentration gradients across mitochondrial membranes is of considerable functional importance (Clausen et al., 1991). Altering mitochondrial ability to maintain these gradients could reduce their ability to produce ATP and lead to the overall OCR drop that was observed in caffeine-treated cells compared to the control. The second possible explanation is that the caffeine treatment irreversibly altered cell metabolic function. Damaged ability to metabolize available fuels could have affected the viability of cells. According to Fernandez et al. (2003) concentrations of caffeine promote cell death in a dose-dependent manner. One investigation found that inhibiting AMP activated protein kinase in the presence of caffeine treatment significantly reduced autophagy in C2C12 cells (Mathew et al., 2014). Therefore, if the cause of decreased mean OCR in caffeine treated cells resulted from autophagy, AMPK activity likely played a part. This could have been an adverse effect of the 24-hour caffeine treatment, thus leaving fewer viable cells to produce ATP, and could explain the decrease in caffeine treated cell mean OCR. This would also explain the similar decrease in mean ECAR measured in caffeine treated cells.

Effect of Caffeine on Metabolic Fuel Use

C2C12 cells treated with caffeine showed a significantly increased utilization of long chain fatty acids and a significant decrease in
Figure 1: (A) Oxygen consumption rate (OCR) of caffeine treated and control muscle cells (n=6). Caffeinated cell OCR shows a significant (p<0.05) drop in both basal and maximal (after FCCP addition) OCR. (B) Extracellular acidification rate (ECAR) of caffeine treated cells also showed a decrease during maximal respiration (after FCCP addition) and lower ECAR values throughout (though not all were statistically significant).
Figure 2: Basal (A) and maximal (B) OCR were significantly ($p<0.05$) lower in caffeine treated cells ($n=6$). Aerobic scope, which is the difference between basal and maximal OCR, was also significantly ($p<0.05$) lower in the caffeine treated cells (C). Proton leak (D) and the amount of OCR dedicated to ATP production during basal metabolism (E) were both comparable ($p>0.25$) between control cells and those treated with caffeine.
Figure 3: (A) Oxidation of glucose as measured by OCR \((n=9)\). The addition of UK 5099 inhibited glucose oxidation, then fatty acid and glutamine oxidation were inhibited by Etomoxir and BPTES. (B) Oxidation of glutamine in OCR \((n=9)\). The addition of BPTES inhibited glutamine oxidation, then glucose and fatty acid oxidation were inhibited by UK5099 and Etomoxir. and (C) Oxidation of fatty acids in OCR \((n=9)\). The addition of Etomoxir inhibited fatty acid oxidation, then glucose and glutamine oxidation were inhibited by UK5099 and BPTES.
Figure 4: (A) Analyses of absolute glucose, glutamine, and fatty acid oxidation in caffeine treated and control cells (n=9). Caffeine induced a significant (p<0.05) decrease in the absolute rate of glucose and fatty acid oxidation. (B) % of total oxidative metabolism of each key fuel in caffeine treated and control cells (n=9). Caffeine also induced a significant (p<0.05) increase in fatty acid oxidation and a decrease in glucose oxidation as a percentage of the total fuel use.
glucose oxidation, when examined as a percentage of total fuel use (Figure 4B). Caffeine has been shown to indirectly increase glucose uptake and fatty acid utilization by activating a calcium-induced AMPK dependent pathway (Raney and Turcotte, 2008). AMPK activity has been shown to increase fatty acid oxidation in human skeletal muscle as well (Wojtaszewski et al., 2003). Similar to the pattern seen in the mitochondrial stress assay, every OCR measurement of all 3 fuel substrates was decreased (though not always significantly) in caffeine treated cells compared to the control. The results of a study by Vaughan et al. (2012) found that low caffeine doses can significantly increase skeletal muscle metabolism, while higher doses can limit this increase. Numerous studies have been done analyzing in vivo effects of caffeine on metabolic fuel utilization; however, countless factors and pathways modulate cellular caffeine responses in whole body organisms (Echeverri et al., 2010, Acheson et al., 2004, Costill, et al., 1978). Some of caffeine’s reported effects on substrate utilization in these studies reflect a similar pattern of decreased glucose and increased fatty acid utilization (Arciero et al., (1995). Thus, the findings of this study are in agreement with similar findings in primary literature, although very little research has been conducted examining the explicit effects of caffeine on mitochondrial substrate utilization in skeletal muscle in vitro. One study conducted by Ukropcova et al. (2005) which collected data in vitro and in vivo subjects found that in vivo insulin sensitivity was related to a higher in vitro capacity for lipid oxidation. However, because caffeine reacts synergistically with epinephrine (Butcher et al., 1968) and causes numerous effects on the somatic nervous system (Krizaj et al., 1999), more research should be conducted examining correlations between in vitro and in vivo studies of insulin resistance.

**Future Work**

Previous studies have identified caffeine as an AMPK activator and have correlated AMPK activation with increased mitochondrial formation in mammals. However, we plan to further investigate C2C12 exposure to caffeine to confirm its effects on metabolism. We are currently conducting metabolic assays to measure cellular energy allocation. Additionally, metabolic alterations can induce structural changes in cells. Therefore, evaluating the connection between environmental caffeine content and possible influence on skeletal muscle physiology may prove crucial to better understand the drug’s induced cellular effects.

**ACKNOWLEDGMENTS**

I would like to thank Dr. Stephen Kinsey for his support and guidance, feedback, and funding for this project. I am also very grateful for the laboratory training provided to me by Dr. Jeff Overton, and thankful for support and comments from Dr. Carolina Priester. Dr. Katherine Bruce, and Dr. Michael Messina. This project was funded in part by the UNCW Center for the Support of Undergraduate Research and Fellowships.
REFERENCES


Binding Of Earth Abundant Metal Coordination Complexes As Molecular Spacers To Single-Walled Carbon Nanotubes

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ABSTRACT
Nanostructured carbon has generated a lot of attention as electrical energy storage materials because of their extreme surface area. To enhance the storage capabilities of these materials, interparticle spacer strategies are needed to preserve the surface area between particles. In this article a comparison of different divalent, dinuclear coordination complexes with strong adsorption to single-walled carbon nanotubes (SWCNTs) will be presented along with the spacer properties that maintain SWCNTs’s electrochemical properties. Dinuclear zinc hydrazone coordination complexes bind with a higher loading than dinuclear ruthenium coordination complexes. Aggregation of SWCNTs happens at a higher ionic concentration when bound to dinuclear zinc hydrazone than dinuclear ruthenium coordination complexes. This is supported by dispersion stability, binding kinetics, and equilibrium data. Membrane resistance data is also presented supporting the complexes acting as molecular spacers in SWCNTs dispersions.

Nanomaterials are paramount to the performance of many technologies because of their extremely high specific surface area (SSA) and surface characteristics. Current technologies are reaching the threshold of their improvement and performance. For example, nanomaterials combined with other molecules have been used in aptasensor designs. A major challenge associated with most nanomaterials is their aggregation, which radically decreases their SSA. In earlier work, long range interactions (LRI) between SWCNTs were explored by investigating tube interactions with various solvated ionic species. The stability of dispersed SWCNTs is dominated by Derjaguin, Landau, Verwey and Overbeek (DLVO) interactions. It was found that the species most effective at collapsing the electrical double layer (EDL) of the nanomaterials were dinuclear coordination complexes with strong binding to the SWCNTs, acting as a molecular spacer between tubes. Below, we present results on coordination complexes that bind to SWCNTs by acting as molecular spacers; however, the coordination complexes do not collapse the EDL as adequately as coordination complexes with bridging ligands. The binding and less effective collapsing of these species leads to higher loading onto the SWCNTs which may increase their dispersion stability. This allows us to utilize SWCNTs SSA for supercapacitor materials. Adsorption kinetics and equilibrium of two divalent, dinuclear metal coordination complexes were compared. The adsorption of the coordination complexes, $^{+2}\text{Zn}_2$ and $^{+2}\text{Ru}_2$, can be understood through LRI such as van der Waals forces, electrostatics, and $\pi-\pi$ interactions. Electrostatic interactions occur between the partial negative surface charge of the SWCNTs and the positive charge of the molecular spacer. Further, $\pi-\pi$ interactions exist between the aromatic ligands of the molecular spacers and the $\pi$ electrons on the SWCNTs. SWCNT’s adsorption capacity
depends on the number of active binding sites available to interact with the adsorbant.\textsuperscript{5} \textit{+2Ru2} bind more strongly to SWCNTs than \textit{+2Zn2}, but the loading is reversed.

\section*{METHODS}

\textbf{Sample Preparation}

The SWCNT were HiPco (Grade P CNT from Unidym, 0.8-1.2 nm diameter, 100-1000 nm length). SWCNT dispersions were made by adding N,N-Dimethylformamide (DMF) (30 mL) to powder (0.5 mg) then tip ultrasonicated for 30 min at 10 W RMS. Following ultrasonication the dispersions were ultracentrifuged at 20000 g for 20 min to deposit undispersed SWCNTs. The supernatant was carefully removed, with the stable dispersion stored for later use. Samples were ultrasonicated for 20 min before use in experiments. All experiments were conducted at room temperature 18-20 \degree C.

\textbf{Molecular Spacers}

Two metal coordination complexes were adsorbed to the SWCNTs as possible molecular spacers. A dinuclear ruthenium coordination complex, \{Cl(2,2';6',2''-terpyridine)Ru(tetrapyrido[3,2-α:2',3'-c:3'',2''-h:2'',3''-j]phenazine)Ru(2,2';6',2''-terpyridine)Cl\}-[PF\textsubscript{6}\textsuperscript{2-}] \textit{(+2Ru2)}\textsuperscript{7}, and a dinuclear zinc coordination complex, 4-(tert-buty1)-2'-6-bis(2-(phthalazin-1-yl)hydrazono)methylphenol(m\textsubscript{2}-methoxy) dizinc(II)-acetate \textit{(+2Zn2)}\textsuperscript{8} were dissolved in dry DMF for binding studies.

\textbf{Binding Kinetics and Adsorption Studies}

Adsorption of molecular spacers to the surface of SWCNTs was performed by adding different concentrations of adsorbent to the dispersion. Samples were ultracentrifuged at 100000 g for an hour to guarantee sediment did not interfere with optical adsorption measurements. The supernatant was pipetted off, and the equilibrium concentration of unbound species was measured using UV-Vis spectroscopy. Measured concentrations were normalized to a pristine SWCNTs control dispersion. The concentration of molecular adsorbate was compared to initial controls to determine the amount bound to SWCNTs. These studies were performed at various incubation periods from 10 to 90 min increasing in 5 min intervals to determine binding kinetics.

\textbf{Membrane Resistance}

Membrane resistance studies were conducted using vacuum filtration across a 9.55x10\textsuperscript{-4} m\textsuperscript{2} 0.272 mg thin film of SWCNTs. The flux of DMF through the membrane was measured with successive 50.0 mL rinses. \textit{+2Zn2}-SWCNTs films were produced by incubating dispersed tubes with 9.04 μM of \textit{+2Zn2} for 90 min. The film was formed by pouring the \textit{+2Zn2}-SWCNTs dispersion onto a 0.45 mm pore polypropylene membrane and vacuum filtered, leaving behind a film of \textit{+2Zn2}-SWCNTs. The filtrate was collected with the amount of coordination complex remaining after each rinse being used to determine q.

\section*{RESULTS AND DISCUSSION}

\textbf{Binding Kinetics and Adsorption Results}

The amount of \textit{+2Zn2} bound to SWCNTs, qe the mg of \textit{+2Zn2} adsorbate per g of SWCNTs adsorbent, was measured versus time. Adsorption kinetics studies were used to find the binding mechanism. The kinetics of \textit{+2Zn2} bound to SWCNTs were measured as a function of initial concentration, \textit{C\textsubscript{0}}, of \textit{+2Zn2}. The concentration of SWCNTs and \textit{+2Zn2} were measured using UV-Vis spectroscopy. Because they do not absorb in the same region, a correction was applied for any remaining SWCNTs in the dispersion as shown in Figure 1. At low \textit{C\textsubscript{0}}, q\textsubscript{t} nears the theoretical maximum packing, q\textsubscript{max}. The initial rates of adsorption were computed from the regression of q\textsubscript{t} versus time.\textsuperscript{9} The binding rate was not dependent on the number of binding sites, supporting an independent binding site model. This pseudo-zeroth-order kinetics
also supports an independent binding model of the $+2\text{Zn}^2+$ complex onto the surface sites of the SWCNTs where $[+2\text{Zn}^2+] = C_0 - k t$. The rate constants $k = 7.3 \pm 0.5 \text{ (mg g}^{-1}\text{) min}^{-1}$ and $k = 7.1 \pm 1 \text{ (mg g}^{-1}\text{) min}^{-1}$ are experimentally the same for different initial concentration $C_0 = 5.71 \text{ mg L}^{-1}$ (b) and $C_0 = 19.0 \text{ mg L}^{-1}$ (a), respectively. The kinetics data are not in agreement with a pseudo-first or pseudo-second-order kinetics models. An adsorption isotherm of $+2\text{Zn}^2+$ intercalating with SWCNTs was made by incubating samples for 2 h before removing the SWCNTs via ultracentrifugation. The equilibrium concentration, $C_{eq}$, was computed using UV-Vis spectroscopy.

Adsorption data was analyzed using a modified Brunauer-Emmett-Teller (BET) isotherm,

$$q_e = \frac{q_m K_s C_{eq}}{(1-K_L C_{eq})(1-K_L C_{eq}+K_s C_{eq})}$$

where $q_m$ is the adsorbate loading of one monolayer, $K_s$ is the equilibrium constant for the adsorbate–SWCNTs surface interaction, and $K_L$ is the equilibrium constant for the subsequent adsorbate layer bound to the first monolayer. A non-linear least squares fit on these parameters to the data (see Figure 2) determined that $q_m = 704 \pm 29 \text{ mg g}^{-1}$, $K_s = 1.1 \pm 0.15 \text{ mg L}^{-1}$, and $K_L = 0.017 \pm 0.002 \text{ mg L}^{-1}$. $q_m*$ is the theoretical maximum packing of $+2\text{Zn}^2+$ could have when π–π stacked onto a flat surface, represented as the highest dashed line in Figure 2. The actual $q_m = 704 \pm 29 \text{ mg g}^{-1}$ is relatively close to $q_m* = 1057 \text{ mg g}^{-1}$, which is surprising as SWCNTs surfaces are curved. Indicated by the middle dashed line in Figure 2, as the adsorption of coordination complex onto the SWCNTs surface ends, the SWCNTs become saturated. At higher concentrations, i.e., above the onset of aggregation $X_o = 14.2 \pm 0.3 \text{ µM}$, some of the SWCNTs will aggregate before adsorption of $+2\text{Zn}^2+$ can happen. After aggregation, the surface is not accessible to the coordination complex. The high ionic concentration of coordination complex destabilizes the dispersions causing aggregation.

The same adsorption studies were carried out for $+2\text{Ru}^2+$ onto SWCNTs surfaces. This coordination complex fully dissociates and is a strong electrolyte in DMF, whereas $+2\text{Zn}^2+$ forms an ion pair in DMF. Both coordination complexes are held together with the same tetrapyridophenazine bridging ligand that is able to π–π stack with SWCNTs surfaces. The heteroligands on the $+2\text{Ru}^2+$ coordination complex hinder the adsorption of the complex onto the SWCNTs surface; this problem is not present in the planar $+2\text{Zn}^2+$ coordination complex. The samples were incubated for 2-3 days at low concentrations because of the slow binding kinetics. The $+2\text{Ru}^2+$ binds stronger to SWCNTs than $+2\text{Zn}^2+$, and the onset of aggregation is much lower at $X_o = 1.22 \pm 0.01 \text{ µM}$. SWCNTs begin to aggregate at much lower concentrations, reducing their surface area. Figure 3 shows the Langmuir isotherm model of the $+2\text{Ru}^2+$ bound to SWCNTs. $K_s$ is essentially zero making the models equivalent with $q_m = 87 \pm 4 \text{ mg g}^{-1}$ and $K_L = 3.5 \pm 0.6 \text{ mg L}^{-1}$. $+2\text{Ru}^2+$ binding constant, $K_s$, is larger than $+2\text{Zn}^2+$ binding constant at $K_s = 1.1 \pm 0.15 \text{ mg L}^{-1}$. This is expected as the ruthenium fully dissociates in DMF and has more delocalization on its ligand.

**Membrane Resistance Results**

We have theorized that our coordination complex acts as a molecular spacer, intercalating with SWCNTs and increasing the distance between tubes. These molecular spacers increase the accessible SSA and the flow rate through condensed films. The membrane resistance (MR) of these thin films can be determined using Darcy’s law

$$K_m = \frac{a \Delta P}{\mu Q}$$

where $\Delta P$ is the differential pressure across the membrane, $a$ is the area of the film, $\mu$ is the dynamic viscosity, and $Q$ is the flux across the membrane. Figure 4 presents the normalized MR of pristine (diamonds) and $+2\text{Zn}^2$-SWCNTs thin films. The MR of pristine films is consistently higher until the fourth rinse,
where the MR of both film types converge. For the $^{2+}\text{Zn}_2$-SWCNTs thin films, the MR increased after successive rinses until the MR stabilized. The MR of the first rinse of the $^{2+}\text{Zn}_2$-SWCNTs thin films is almost half that of the pristine thin film. There is an increase in MR of the $^{2+}\text{Zn}_2$-SWCNTs thin films as the $^{2+}\text{Zn}_2$ is washed off after each rinse.

CONCLUSIONS

Using the large SSA of SWCNTs, electrical energy from renewable sources can be stored using a double layer capacitance mechanism. We have used molecular spacers to prevent the aggregation of the SWCNTs such that their SSA can be used for energy storage applications. We studied the binding kinetics and equilibrium of two different coordination complexes that intercalate between the SWCNTs in dispersions and in thin films. The $^{2+}\text{Ru}_2$ complex binds more strongly to SWCNT surfaces then does the $^{2+}\text{Zn}_2$ complex; however, the loading onto the SWCNTs is much lower for the ruthenium complex. In addition, ruthenium is too expensive of a metal to make ruthenium-based molecular spacers a viable option. Improving molecular spacer design and application can help ensure a future with less non-renewable energy sources. Energy storage devices based on our molecular spacer results have shown promise. Other metal coordination complexes are being investigated that are more earth abundant and cost effective. In future studies, coordination complexes with enhanced oxidation-reduction activity will be tested and characterized. We have shown that molecular spacers with high $\pi$ conjugation and steric bulk on the ligands, along with low charge on the metal center, perform the best for electrical energy storage applications.

Figure 1. Adsorption kinetics of $^{2+}\text{Zn}_2$ bound to SWCNT dispersed in DMF. As the initial concentration of adsorbate increased so does the amount of complex bound to the SWCNT, until saturation. Initial adsorption rates are constant with time, making them quasi-indepen- dent of adsorbate concentration.
Figure 2. Adsorption isotherm of $+2Zn^2+$ onto a SWCNT. The theoretical max packing, $q_m^*$ is shown as the highest dashed line. The inset is the molecular spacer intercalating with a SWCNT.

Figure 3. Adsorption isotherm of $+2Ru^2+$ onto a SWCNT surface. The $C_{eq}$ of adsorbate is measured after the SWCNT have been centrifuged out of the dispersion.
Figure 4. Membrane resistance of pristine SWCNT (diamond) and $+2\text{Zn}^2-$SWCNT thin films. The membrane resistance of the $+2\text{Zn}^2-$SWCNT thin films increases with successive DMF rinses.
REFERENCES


Sensitivity Analysis of Nanoparticle Concentrations in Wastewater Treatment and Biosolid Application for Environmental Risk Assessment

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North Carolina School of Science and Mathematics
Faculty Mentor: Jacelyn Rice and Mark Wiesner
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ABSTRACT
Nanoparticles (NPs) exhibit novel properties that can enhance many industrial processes and products, but also pose risks to the environment. As the presence of NPs in consumer society increases, it becomes critical to model their uncertain and potentially toxic fates when released into aquatic and terrestrial systems. Most NPs are predicted to end up in sewer systems and eventually in wastewater treatment plants (WWTPs), where they either are discharged into receiving streams or accumulate in biosolid waste. However, considerable uncertainties exist in model inputs, which vary between NP species and will inevitably change with future resource consumption, NP production, and climate. In this project, a sensitivity analysis was devised for a series of models describing NP pathways through WWTPs and land application units (LAUs) for biosolids. Findings include: (1) for WWTPs, the most influential inputs are transformation rate coefficients, residence times, and source values (of either NPs or wastewater); (2) for LAUs, the most important factor in predicting NP fate is erosion by runoff; and (3) the source of variance among outputs is dependent on the NP core. These results pinpoint the most significant factors in predicting environmental NP concentrations and provide insight on processes that drive NP fate and transport, on implications of changes related to NP life cycles, and on areas of research that would be most effective in accurately assessing NP exposure in the future.
especially sensitive to uncertainty in global production and release rates [8]. Estimates of these rates vary by orders of magnitude [5].

Most NPs are predicted to enter sewer systems and then wastewater treatment plants (WWTPs) [3], where they will subsequently either exit into receiving streams as part of wastewater effluent, or accumulate in “biosolid” sludge to be applied to agricultural lands as fertilizer [9]. In the absence of more detailed studies, many assumptions must be made about the impact of WWTP processes such as transformation and distribution on the fate of nanoparticles. Great variability has been reported for soil erosion rates [10] and regional precipitation [11], [12]. NPs are also often stabilized against aggregation by coatings, or functionalization. Because these coatings dictate toxicity and surface properties, it is reasonable to assume that NPs will behave differently under different surface modifications and may be strongly influenced by different input parameters.

In addition, values for such parameters are projected to shift with trends in global climate, population, and economy. Production rates will likely increase due to rising demand from industries and growing resource consumption. River flow regimes and annual runoff rates are expected to significantly change by the year 2050 [13], which will impact NP concentrations in waterways irrespective of increases in production rate. Precipitation and soil erosion rates are expected to vary dramatically over the next century due to climate change [14]. Understanding the implications of these trends on NP exposure models is essential to preserving the health of the global environment.

Sensitivity analyses are useful in providing insight on such uncertainties and variations. Analyses generally seek to determine how variations in model outputs are attributed to the variations and correlations among model input parameters, and are useful in finding critical control points and verifying model robustness [15]. In the context of NPs, they can provide a better understanding of how environmental NP concentrations are specifically influenced by the factors used to predict them. By identifying which terms are important and merit special attention within the assigned values, they can help drive the direction of future lab-scale research in support of the model.

In this paper, we devised a sensitivity analysis for a series of models describing NP pathways through WWTPs and biosolid land application (land application unit [LAU]). We aim to identify the most significant inputs in the model and answer the following questions: (1) Which process or processes mainly drive NP fate in the environment? (2) How does sensitivity differ between NP species and coatings? (3) How are environmental NP concentrations projected to change? (4) How can additional areas of research be prioritized to optimize exposure models and more accurately assess NP exposure in the future?

**METHODOLOGY**

In this study, we analyzed two models: (1) a steady state solution describing NP concentrations through the WWTP model, and (2) a time-dependent solution describing NP exposure in soil as predicted by the LAU model. The WWTP model had four NP concentration outputs, and the LAU model had outputs of steady state NP concentration \(q_s\) and time to achieve steady state \(t_s\). We employed two methods of sensitivity analyses – partial derivative analysis and nominal range graphical analysis. R, a statistical software environment, was used with the former method to evaluate all concentrations [16], while Mathematica, a computational software program, was used with the latter method to analyze \(t_s\) only [17].

2.1 WWTP Model description

The WWTP model is composed of four independent but interconnected compartments: the initial sewer system, primary treatment including primary clarification, secondary treatment consisting of activated sludge and secondary clarification, and anaerobic digestion. NPs are subjected to major processes of:
anaerobic redox transformation in the sewers and anaerobic digestion; aerobic transformation elsewhere; and distribution between liquid (supernatant) and solid (sludge) phases in primary and secondary treatment, where settling occurs. Table 1 lists WWTP model inputs; numerical input ranges were obtained from literature. Detailed model description and input parameterization can be found elsewhere [5].

We investigated a steady state solution for NP concentrations in various components of the WWTP [5] for three NPs (zinc oxide [ZnO], silver [Ag], and titanium oxide [TiO$_2$]), which are known to behave differently in solution and are all among the most widely used in consumer technologies [2]. Additionally, to determine how sensitivity differs based on size or surface modifications, we compared four types of functionalized Ag NPs: polyvinylpyrrolidone (PVP) coated Ag with diameters of 40 and 8 nm, and gum arabic (GA) coated Ag with diameters of 25 and 6 nm. For all NPs, four outputs were analyzed: the concentration of NPs present in effluent as native ($C_{s1}$) and transformed ($C_{s2}$) species, and those present in biosolids as native ($C_{b1}$) and transformed ($C_{b2}$) NPs. Effluent concentrations were calculated in mg/L and biosolid concentrations were calculated in mg/g as mass of NPs/mass of sludge.

2.2 LAU model description

Over half of all nutrient-rich biosolids produced by wastewater treatment are reused as fertilizer on agricultural soils [9]. The LAU model describes a typical land application unit with a mass loading of NP-laden biosolids; the concentration of these NPs was estimated following the WWTP model. NP fate is subsequently impacted by processes of: transformation, bio-uptake into plants and bacteria, erosion by rainfall via surface runoff, and leaching after mobilization from the solid phase.

Table 2 lists LAU model inputs; numerical input values were similarly obtained from literature. We assumed biosolids would be applied to an average tillage depth ($d_{till}$) of 25 cm [18] with a soil density (1 - $\varepsilon$) of 1.25 g/cm$^3$ [19], [20]. Bio-uptake rates were obtained from a review by Schwab et al. [21] and annual rainfall data was collected by the NOAA [22], [23]. This model was investigated only for ZnO NPs as field data was not available for other compounds. Further description and parameterization, including rates of biosolid application and NP leaching, can be found elsewhere [5].

We analyzed a time-dependent solution for concentration of NPs. Two scenarios were considered: a lower bound assuming low loading of biosolids and high rainfall (R), and an upper bound assuming high loading and low rainfall (L) [5]. Model outputs for both scenarios were steady state concentrations of the NPs ($q_i$) in mg/kg as mass of NPs/mass of soil, and time to achieve steady state ($t_s$) in days.

2.3 Sensitivity analysis formulation

Sensitivity analyses may be broadly classified as mathematical, statistical, or graphical [15]. Various methods have been comprehensively reviewed [15], [24], and it is noted that different methods are likely to produce slightly different “sensitivity rankings” of input parameters. However, analyses generally aim to identify the most significant model inputs in order to gain a better understanding of how model outputs vary, how they might be projected to change, and how their accuracy can most precisely be improved. As such, the exact ordering of inputs is not as useful as the identification of a group of variables that consistently appear among the most sensitive. In this project, we devised two methods: partial derivative analysis and nominal range graphical analysis. Both are local (i.e. they examine local behavior) and are suitable because the WWTP and LAU models were analyzed at steady state.

2.3.1 Partial derivative analysis

Differential analysis is one of the most commonly used sensitivity analysis techniques because it is the underlying concept behind almost all other methods [24]. In this
<table>
<thead>
<tr>
<th>Parameter description</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Influent volume of wastewater</td>
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<tr>
<td>NP loading to WWTP</td>
<td>Source</td>
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<tr>
<td>Distribution coefficient in:</td>
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<tr>
<td>primary clarification</td>
<td>$\gamma_1$</td>
</tr>
<tr>
<td>secondary clarification</td>
<td>$\gamma_2$</td>
</tr>
<tr>
<td>sewers</td>
<td>$\theta_{sewer}$</td>
</tr>
<tr>
<td>Hydraulic residence time in:</td>
<td></td>
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<tr>
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<td>$\theta_p$</td>
</tr>
<tr>
<td>secondary treatment</td>
<td>$\theta_s$</td>
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<tr>
<td>Solids residence time in:</td>
<td></td>
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<tr>
<td>secondary treatment</td>
<td>$\theta_a$</td>
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<tr>
<td>anaerobic digestion</td>
<td>$\theta_d$</td>
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<td>$X_{s1}$</td>
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<tr>
<td>secondary clarification</td>
<td>$X_{s2}$</td>
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<tr>
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</tr>
<tr>
<td>anaerobic transformation</td>
<td>$k_{anaerobic}$</td>
</tr>
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Table 1. Input parameters for the *WWTP* model.

<table>
<thead>
<tr>
<th>Parameter description</th>
<th>Parameter</th>
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<td>NP concentrations in biosolids</td>
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<td>Biosolid application rate</td>
<td>biosolid loading</td>
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<tr>
<td>Depth of till</td>
<td>$d_{tilt}$</td>
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<tr>
<td>Fraction of till available for erosion by runoff</td>
<td>$f_{cr}$</td>
</tr>
<tr>
<td>Soil density</td>
<td>$1 - \varepsilon$</td>
</tr>
<tr>
<td>Plant uptake rate coefficient</td>
<td>$P_{uptake}$</td>
</tr>
<tr>
<td>Annual rainfall</td>
<td>$R$</td>
</tr>
<tr>
<td>Transformation rate coefficient</td>
<td>$k_t$</td>
</tr>
<tr>
<td>Fraction of NPs available for leaching</td>
<td>$f_l$</td>
</tr>
<tr>
<td>Fluid available for infiltration</td>
<td>$R_l$</td>
</tr>
</tbody>
</table>

Table 2. Input parameters for the *LAU* model.
study, we evaluated local sensitivity as the partial derivative of the output with respect to small variations in the inputs. For each parameter, we also multiplied the partial derivative by the variation in its range of values, in order to obtain a measure of its importance. That is, if a dependent variable (output) $O$ is modeled as a function of $n$ independent variables (inputs) $I$, i.e. $O=f(I_1, I_2, \ldots, I_n)$, then output variation due to a specific input $I_k$ is calculated as in Equation 1, where $\Delta I_k$ is the variation in $I_k$. Total output variation is then the sum of the variation contributed by all inputs, to the first order, as stated in Equation 2.

$$\Delta O_k = \frac{\partial O}{\partial I_k} \times (\Delta I_k) \text{ for } k = 1, 2, \ldots, n \quad (1)$$

$$\Delta O = \sum_{k=1}^{n} \Delta O_k \quad (2)$$

In addition, the relative contribution, or importance, of a specific input $I_k$ is the ratio of its contribution to output variation ($\Delta O_k$) to the total output variation ($\Delta O$). Sensitivity defined by our method is an indication of both significance and variability, as sensitivity can be a result of an input parameter’s (1) high correlation with the output, such that any change in the input is noticeably reflected in the output; or (2) own large variability, such that this variability is propagated through to the model output [24].

We computed numerical partial derivatives at steady state. To illustrate the variation in input parameters and the stochastic nature of environmental NP fate, we used Monte Carlo simulations and represented model inputs by probability distributions when applicable. Monte Carlo simulations sample inputs from a predefined distribution of values to produce a number of outputs, which provide a sense of the range of possible model outcomes and the associated uncertainties as opposed to a single deterministic value. In this study, models were sampled 10,000 times. Input distributions were selected from literature; when data was lacking, the distribution was assumed to be normal with a variability of 10% [5]. We evaluated partial derivatives using median values, as they are the most stable statistical measure for anchoring sensitivity [25]. Variation in inputs ($\Delta I_k$) was calculated as the difference between the 5th and 95th percentiles.

### 2.3.2 Nominal range graphical analysis

In addition to steady state concentrations of NPs predicted by the LAU model, the time at which steady state was achieved ($t_s$) was also studied. We approximated this by plotting NP concentration over time, and subsequently analyzed sensitivity of $t_s$ to LAU model inputs using nominal range graphical analysis. Each input parameter was varied across its expected range while all others were left at fixed “nominal” values. The resulting difference in either time or concentration, referred to as the swing weight of the model [26], provides an idea of the sensitivity of the model output to that parameter. We employed this analysis for four LAU model inputs – $d_{\text{tilt}}$, $f_{\text{er}}$, $(1 - \varepsilon)$, and $P_{\text{uptake}}$ – whose expected ranges and nominal values were chosen from literature, as shown in Table 3.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Nominal value</th>
<th>Min</th>
<th>Max</th>
<th>Reference</th>
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<td>cm</td>
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<td>18</td>
<td>33</td>
<td>[18]</td>
</tr>
<tr>
<td>$1 - \varepsilon$</td>
<td>g/cm³</td>
<td>1.25</td>
<td>1.1</td>
<td>1.6</td>
<td>[19], [20]</td>
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<tr>
<td>$P_{\text{uptake}}$</td>
<td>cm/day</td>
<td>0.0011</td>
<td>0.000627</td>
<td>0.0066</td>
<td>[21]</td>
</tr>
<tr>
<td>$f_{\text{er}}$</td>
<td>-</td>
<td>0.1</td>
<td>0</td>
<td>1</td>
<td>-</td>
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</tbody>
</table>

Table 3. Nominal values and expected ranges investigated for four LAU model inputs.


RESULTS

3.1 Sensitivity of WWTP output concentrations

The variance in WWTP model outputs ($C_{s1}$, $C_{s2}$, $C_{b1}$, $C_{b2}$), organized by the relative contribution of each model input, is summarized in Figs. 1, 2, and 3. These figures illustrate sensitivity among NPs with cores of Ag, ZnO, and TiO$_2$, respectively.

Sensitivity does not vary among Ag NPs of different functionalization and sizes, taking into account inherent randomness in Monte Carlo modeling. Output variation in all four types of Ag was found to have the distribution of model inputs shown in Fig. 1. Thus, for the purposes of future comparison, the four types can be taken together as a single type of general Ag NP. All native NP concentrations in both effluent and biosolids are most sensitive to the anaerobic transformation rate coefficient ($k_{anaerobic}$). This coefficient was used to parameterize both the sewer system and anaerobic digestion, though the two compartments may have different rates in a realistic WWTP [5]. NP transformation byproduct concentration in wastewater effluent is most sensitive to the suspended solids concentration in secondary clarification ($X_{s2}$, accounting for ~41% of the output variation) and that in biosolids is most sensitive to the solids residence time in anaerobic digestion ($\theta_d$, ~41% of output variation). In general, variations in transformation byproduct concentrations tend to be most influenced by residence times and input amounts (of either NP loading or influent wastewater).

Sensitivity varies between NPs of different cores. Fig. 2 illustrates output variation for ZnO NPs and Fig. 3 shows the data for TiO$_2$. Native ZnO and Ag NP concentrations in both effluent and biosolids are dominated by transformation coefficients, aerobic in the case of ZnO and anaerobic for Ag. These coefficients account for over 95% of output variance. Varying the coefficient by an order of magnitude can shift the output concentration by up to 105.

Transformation byproduct concentrations of ZnO and Ag NPs are also similar, again noting the inherent randomness of Monte Carlo simulations. Sensitivity in TiO$_2$ transformation byproduct concentrations is not reported because TiO$_2$ does not readily undergo redox reactions and so these concentrations were assumed to be zero [5]. Variance in native TiO$_2$ NP concentrations is attributed to the same distribution of model inputs influencing variance in ZnO and Ag transformation byproduct concentrations.

3.2 Sensitivity of LAU model outputs

For both low loading/high rainfall (R) and high loading/low rainfall (L) scenarios, the variance in steady state concentrations of ZnO NPs in soil ($qs$) organized by the relative contribution of LAU model inputs is summarized in Fig. 4. The impact of varying LAU model parameters through their nominal ranges is illustrated in Fig. 5-8, and resulting changes in $t_s$ are summarized in Table 4.

Sensitivity varies slightly between high and low loading scenarios, with the fraction

<table>
<thead>
<tr>
<th>Parameter varied</th>
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<th>low rainfall, high loading (L)</th>
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<tr>
<td>$d_{all}$</td>
<td>min 30</td>
<td>max 150</td>
</tr>
<tr>
<td>$d_{all}$</td>
<td>max 40</td>
<td>min 120</td>
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<tr>
<td>$P_{uptake}$</td>
<td>min 30</td>
<td>max 150</td>
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<tr>
<td>$P_{uptake}$</td>
<td>max 30</td>
<td>min 150</td>
</tr>
<tr>
<td>$f_{er}$</td>
<td>min 650</td>
<td>max 20</td>
</tr>
</tbody>
</table>

Table 4. Time ($t_s$) in days to reach steady state concentrations of NPs in soil based on variation in LAU input parameters. For instance, in the high rainfall/low loading scenario, $t_s$ is 650 when $f_{er}$ is set at the maximum and $t_s$ is 4 when $f_{er}$ is at its minimum.
Figure 1. Variance in WWTP output concentrations as contributed by model inputs for Ag NPs. Sensitivity was identical among Ag PVP 8nm, Ag PVP 40nm, Ag GA 25nm, and Ag GA 6nm NPs. Only major inputs (contributing ≥1%) are labeled.
Figure 2. Variance in WWTP output concentrations as contributed by model inputs for ZnO NPs. Only major inputs (contributing ≥1%) are labeled.
Figure 3. Variance in WWTP output concentrations as contributed by model inputs for TiO\textsubscript{2} NPs. Only major inputs (contributing ≥1%) are labeled. Note that sensitivity in transformation byproducts are not reported because TiO\textsubscript{2} does not readily undergo redox.
Figure 4. Variance in soil concentration of ZnO NPs as contributed by LAU model inputs for two loading scenarios. Only major inputs (contributing ≥1%) are labeled.
Figure 5. NP concentration over time by varying $f_e$. The graphs on the right are scaled versions of those on the left within the dotted box. Note the different scales in both the horizontal and vertical axes between all figures.
Figure 6. NP concentration over time by varying $P_{\text{uptake}}$. Note the different scales in both the horizontal and vertical axes between the two figures, and that all three lines are nearly identical in each figure.
Figure 7. NP concentration over time by varying $(I - \varepsilon)$. Note the different scales in both the horizontal and vertical axes between the two figures.

Figure 8. NP concentration over time by varying $d_{\text{eff}}$. Note the different scales in both the horizontal and vertical axes between the two figures.
of soil depth available for runoff erosion \( f_{er} \) accounting for over 80% of the variance in steady state NP concentration for both (Fig. 4). This fraction is also the major contributor to time to reach steady state, as changing \( f_{er} \) dramatically impacts \( t_s \) (Table 4 and Fig. 5). In contrast, the plant uptake rate coefficient \( P_{uptake} \) plays a minimal role in determining both model outputs, as it does not significantly affect time to achieve steady state (Table 4 and Fig. 6) and has negligible influence in steady state concentrations (Fig. 4). In the case of steady state concentrations, \( P_{uptake} \) is more noticeable in the low loading scenario; this is perhaps better interpreted as a relatively more influential role due to a relatively lesser influence of erosion by runoff, as a result of lower rainfall. Biosolid loading rates and rainfall play higher and lower roles, respectively, in concentrations for the high loading/low rainfall scenarios, as expected due to scenario specifications. Lastly, soil density \((1 - \varepsilon)\) and depth of till \( d_{till} \) are both minor contributors to LAU model outputs. Soil density affects steady state concentrations more significantly than it does time to reach steady state; this is illustrated by the difference in NP concentration over time as soil density is varied across its nominal range (Fig. 7). The opposite is true for \( d_{till} \); as it is varied across its nominal range, NP soil concentration rises at different rates but plateaus at the same steady state value (Fig. 8).

**DISCUSSION AND IMPLICATIONS**

In this project, functionalized Ag NPs were analyzed under the same assumptions and differ only in their distribution coefficients \( \gamma_1 \) and \( \gamma_2 \). As we show that these coefficients play negligible roles in determining NP concentrations in WWTPs, it is reasonable that the relative contributions of their remaining model inputs are identical (Fig. 1). In contrast, NPs of Ag and ZnO cores differ by transformation rates in addition to distribution coefficients, and this is reflected in their variations in native NP concentrations (circles \( C_{si} \) and \( C_{ti} \) in Fig. 1 and 2). Previous research indicates that for ZnO NPs, aerobic transformation occurs much faster than anaerobic; for Ag NPs, anaerobic transformation is more rapid [5]. This suggests that the rate of transformation has implications for sensitivity: slower reactions appear to play a lesser role in determining final output concentrations. We note, however, that due to insufficient data these reactions were assumed to be first order and irreversible – a possible oversimplification. Further research on NP redox transformation would improve the accuracy of this analysis.

The apportionment of model inputs contributing to variation for native TiO\(_2\) NP concentrations correlates with that for transformed Ag and ZnO NP concentrations. Because TiO\(_2\) does not undergo transformation, all TiO\(_2\) NPs exit the WWTP in their native form. High transformation rates of Ag and ZnO, in both effluent and biosolids, indicate that most Ag and ZnO NPs are released from the WWTP as transformed by-products. Thus, this apportionment appears to reflect the sensitivity to model inputs of the dominant NP form exiting the WWTP, with dominance dictated by the NP core. Most sensitive factors include suspended solids concentration in secondary treatment (~41% of output variation), solids residence time in secondary treatment (~22.5%), and source values (~20%) for wastewater effluent; they include solids residence time in anaerobic digestion (~41%) and source values (~30%) for biosolids. In more accurately assessing future NP exposure concentrations leaving WWTPs, these factors should be areas of active investigation.

Suspected solids concentrations and residence times are specific to individual WWTPs, suggesting that NP concentrations in wastewater effluent and biosolid wastes vary between WWTPs even with equivalent NP loadings. All concentrations, however, can be expected to rise as consumer demand and global production of NPs increases, due to the significant influence of source values. Combined with water level changes predicted in streams and rivers over the next
several decades, this may indicate great variation in future NP concentrations in surface waters with potential implications for aquatic ecosystem health.

Analysis of LAU model outputs indicates that erosion by runoff is most effective in predicting NP concentrations in soil, suggesting that erosion is the key process driving NP fate through agricultural lands where sludge containing nanomaterials is applied. Plant uptake, in contrast, is not a sensitive factor for either steady state NP concentrations or time to achieve steady state. This carries significance in future model projections. As rainfall in some areas increases due to climate change, we expect a significant portion of NPs remaining in biosolid-applied soils to wash into surface waters as agricultural runoff, again with potential implications for ecosystem health. We also expect a decrease in the amount of remaining NPs available for plant uptake on land, though analysis suggests that this secondary effect is negligible.

**CONCLUSIONS AND FUTURE WORK**

In this project, we devised a sensitivity analysis for two models describing TiO$_2$, Ag, and ZnO NP pathways through a WWTP and subsequent land application. For all NP compounds, WWTP output concentrations appear to be most sensitive to transformation rate coefficients, residence times, and source values (NP loading and influent wastewater). The faster transformation reaction plays a more dominant role. Sensitivity is dependent on NP core but independent of surface functionalization and size. Analysis suggests that output concentrations of NPs vary between individual WWTPs even with equivalent loadings, but all concentrations can be expected to rise as global NP production rates increase, with potential implications for aquatic ecosystem health. For ZnO NPs applied to agricultural lands, erosion by runoff is the dominant factor in predicting steady state soil concentrations. We expect increasing rainfall in some areas due to climate change to result in significantly more NPs leaving biosolid-applied soils as surface runoff, again with potential implications for ecosystem health.

This project represents an important step towards optimizing the model for future applications. The results provide insight on key processes driving NP fate in the environment, thereby laying the groundwork for practical strategies in minimizing risks associated with our usage and disposal of consumer products. For instance, agricultural areas where NP-containing biosolid fertilizer is used can be managed with more specific and informed decisions, given the predicted impacts revealed by this analysis. Knowing the associations between NP soil concentration and different factors such as the degree of erosion and plant uptake, or increasing/decreasing rainfall, is valuable when considering aquatic and terrestrial ecosystem health. Project outcomes also shed light on areas of investigation that would be most effective in more accurately assessing NP exposure in the future, thus helping to drive the direction of further lab-scale research. Future work includes: (1) incorporating results into exposure models and observing subsequent differences in predicted NP concentrations; (2) applying our methods to other exposure models, comparing sensitivity rankings, and assessing how rankings are related to the structure and conditions of the model; (3) gathering input parameter data on common NPs apart from those studied in this project (ex. gold) through both computational and experimental methods, so that we may investigate sensitivity for a wider range of compounds; and (4) analyzing models that describe alternate NP pathways beyond WWTPs and subsequent biosolid application, to gain a broader understanding of factors influencing global NP prevalence in the environment.
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Comparison of Seed Profiles Using Attenuated Total Reflectance Fourier Transform Infrared Spectroscopy in a Stress-Tolerant *Zea mays* Genotype, Mo276, from Control and Low-Nitrogen Field Conditions

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**ABSTRACT**

Maize is widely produced and has substantial economic importance. Environmental conditions such as nitrogen fertilizer amounts could affect starch and lipid concentrations in maize kernels and thus affect the economic and nutritional value of the crop. Lower levels of nitrogen are known to slightly decrease the amount of starch and lipid in some maize genotypes as measured with spectroscopy and chemical extraction. Selecting a resilient genotype for crop production would be useful to farmers. Kernels from the maize genotype Mo276 were subjected to Fourier Transform Infrared Spectroscopy Attenuated Total Reflectance to measure kernel composition. Four kernels from the control environment and three from a low nitrogen environment were compared and reflectance in the spectrum that is diagnostic of the presence of decreased starch in kernels grown with less nitrogen was obtained, though in this genotype there was no significant effect of nitrogen treatment on starch. The impact of low nitrogen on lipid concentration was also not significant. Using spectroscopy may be helpful for rapid detection of genotypes with starch differences and thus breeding for higher starch under low nitrogen conditions that are common globally. The preliminary results from these samples can be used for further research in a larger study.

Corn, *Zea mays* L., is economically valuable and widely produced (http://www.nass.usda.gov). It is an important crop that has been utilized for animal food, but it also has uses in the human diet, seeds and raw materials found in food, cosmetics, and pharmaceuticals (Kuhnen et al., 2010). In order for maize to thrive in the fields, certain genotypes are selected that have greater stress resistance or tolerance (Subedi and Ma, 2009). Two environments that impact maize yield are drought conditions and low nitrogen in the soil. Nitrogen is an important factor for the growth of maize; lack of nitrogen will significantly reduce yield (Subedi and Ma, 2009). Nitrogen levels affect the synthesis of fatty acids, which will determine the composition of oil in maize kernels. Typically, the lipid concentration will decrease with a lack of nitrogen but it will not severely impact yield (Blumenthal et al., 2008). Nitrogen deprivation causes a slight accumulation of starch in the leaves of maize but overall, starch levels are decreased with lack of nitrogen (Schlüter...
FT-IR measures the vibrations of bonds present in specific functional groups of the sample (Kuhnen et al., 2010). The instrument measures the energy from the vibrational ground state to the excited state that the atoms in the sample have produced. The FT-IR has a source that emits infrared energy; this will then pass through the sample. The interferometer controls how much energy will pass to the sample (Quintás et al., 2008). With the ATR, the sample sits on a diamond or zinc selenide prism, where the infrared beam will reflect. The wave from the prism is internally reflected to the back of the prism.

Small farmers have grown a variety of maize and allowed interbreeding, which leads to new genotypes. This maintains genetic diversity and preserves certain traits (Kuhnen et al., 2010). To analyze genetically improved maize genotypes, we used a specific genotype samples from a structured population (Lee et al., 2002). Inbreeding after crossing of B73 and Mo17 took place in order to produce the recombinant inbred genotype Mo276 (Lee et al., 2002); this genotype was ranked as stress resistant in prior tests (Stapleton, personal communication).

Chemical analysis can be completed on kernels to determine molecular composition; however, this method destroys the sample and requires large amount of sample (Baye et al., 2006). Research has been completed with near infrared spectroscopy that is measured in reflectance or transmittance. Sampling whole kernels is a fast method that keeps the kernels intact. One issue with analyzing whole kernels is the internal structure within a kernel can vary and the near infrared will not pick up those deviations (Baye et al., 2006).

Attenuated Total Reflectance Fourier Transform Infrared Spectroscopy (ATR FT-IR) is a useful method to identify the chemical composition in maize better than near infrared transmittance (NIT) and near infrared reflectance (NIR). ATR FT-IR spectroscopy has been used in previous studies to determine the unique protein, oil, and starch amounts in a variety of maize genotypes. In the study completed by Kuhnen et al. (2010), maize kernels were milled and then placed on the crystal of the ATR. First a background spectrum was taken of the clean crystal, and then the maize flour was added and compressed onto the crystal (Kuhnen et al., 2010).

FT-IR measures the vibrations of bonds present in specific functional groups of the sample (Kuhnen et al., 2010). The instrument measures the energy from the vibrational ground state to the excited state that the atoms in the sample have produced. The FT-IR has a source that emits infrared energy; this will then pass through the sample. The interferometer controls how much energy will pass to the sample (Quintás et al., 2008). With the ATR, the sample sits on a diamond or zinc selenide prism, where the infrared beam will reflect. The wave from the prism is internally reflected to the back of the prism.

ATR FT-IR is a surface sensitive mechanism with the absorption affected by the sample contact with ATR. If the sample is a solid, the wave cannot penetrate the entire subject. A larger reflectance is equivalent to a larger penetration of the beam into the sample (Kuhnen et al., 2010). The beam will then pass into a detector that will make the final measurements and send the results to the computer for processing and the production of the FT-IR spectrum that can be used in the subsequent analysis (Quintás et al., 2008). The FT-IR spectrum includes an extensive number of data points, so to analyze the results, multivariate tests are used (Kuhnen et al., 2010).

The ATR FT-IR detects components in the maize at different wavelengths. Starch appears in the wavenumber region from 1200-800 cm\(^{-1}\), lipid at 2924, 2854, 1740 cm\(^{-1}\), and protein around 1650-1550 cm\(^{-1}\). The amount of starch, lipid, and protein in a kernel is partially controlled by the genetics of the kernel (Kuhnen et al., 2010). Corn is comprised of 72% starch and 5% oil (Blumenthal et al., 2008). The embryo of a kernel holds the highest amount of oil, so in order to obtain accurate results, it is necessary to use a method that can view the embryo (Baye et al., 2006).

Through breeding, certain maize genotypes can be selected that are resistant to abiotic and biotic factors but maintain normal levels of starch and lipid in the kernel (Kuhnen et al., 2010). Since maize is an
important crop, further research will help keep the crop production stable. Our study with Mo276 was completed to determine if a low nitrogen environment impacted the percent transmittance of the IR spectrum when compared to kernels from a controlled environment. By analyzing the spectrum, differences between the control kernels and low nitrogen kernels can be discerned by comparing the typical wavenumbers associated with starch and lipids. A more resistant genotype, Mo276, is expected to not be affected by lower nitrogen levels in the soil, and the use of FTIR-ATR can provide a faster method of detection to determine this resistance.

MATERIALS AND METHODS

Experimental Design and Kernel Samples.

The experimental design for the kernels that were used came from Manching et al. (2014), which outlines both the amount of nitrogen in the soil along with the control values. The kernel seedlings were planted at the North Carolina Central Crops Research Station (35.66979°, -78.4926°) on April 16, 2012 (Manching, et al., 2014). The genotype, Mo276, was analyzed from the low nitrogen and control treatment. Four kernels from the control treatment and three kernels from the low nitrogen treatment were ground with a mortar and pestle. Although, each kernel was from a different cob, all were grown and harvested at the same time. Before and after each kernel was analyzed using the ATR FT-IR a background reading was collected and automatically subtracted from the sample measurements. Blank samples were also collected to determine if the background had removed the water and carbon dioxide from the atmosphere. The kernels were kept in envelopes stored in a plastic container and were placed in the freezer every few months to ensure no insects were living in the samples. This treatment does not impact the chemical composition of the kernels.

ATR FT-IR.

The Thermo Nicolet 6700 FT-IR (Thermo Electron Corporation, Madison, WI) a class I laser product, was used with the Smart Performance ATR attachment in order to measure the reflectance of a solid. OMNIC spectra software, provided by the manufacturer, was used with the FT-IR to collect data from the samples. A zinc selenide (ZnSe) crystal was used as the trough plate. The detector on the FT-IR was a deuterated triglycine sulfate detector (DTGS) set to perform 100 scans a minute at a resolution of 4 cm\(^{-1}\). The data was collected in percent reflectance which can be converted to percent transmittance. The percent reflectance indicates how much light was able to reflect off the mirrors and reach the detector. The background was initially collected in order to correct for any possible water or carbon dioxide in the air chamber. To collect background, the instrument is run with no sample; however, the software had a background feature that corrected for the atmosphere and shows the user what peaks will be taken out from the sample spectrum. An infrared beam was passed through the sample by reflecting it off the crystal and into the detector, which determined how much of the infrared radiation was reflected and absorbed. The milled kernels were placed directly onto the ZnSe crystal and a slip clutch pressure tower was lowered onto the sample to allow for optimum contact with the crystal.

Statistical Analysis.

Graphs were constructed using R (R Core Development Cite Team, University of Auckland, New Zealand). Using the OMNIC software, peaks were selected using the peak finder option in order to reference in further analysis. JMP Pro 11 (SAS, Inc. Cary, NC) was used to complete multiple statistical analyses. The first analysis was a discriminant multivariate method. A stepwise analysis was used to calculate p-values for all wavenumbers. The summed wavenumbers for starch, 800 through 1250 cm\(^{-1}\) were used for specific comparisons. A Wilcoxon test was performed on the starch wavenumbers that were standardized based on the value at 2250 cm\(^{-1}\). This value was used to correct the values
because the spectra did not have any troughs or peaks in this region. A power calculation was performed for the starch-region comparisons. Further method details and code for the analyses can be found in Zuelsdorf (2016).

RESULTS

Background spectra with no kernel material were collected to determine the effects of water and carbon dioxide in the instrument on the spectral signal. The H2O bending trough appeared around 1595 cm⁻¹ with the CO₂ asymmetrical trough appearing around 2349 cm⁻¹ (see Figure 1). The background transmittance was extremely low because the instrument was given adequate time to warm up and adjust to the atmosphere conditions.

To ensure the background was factoring out water and carbon dioxide, a blank sample was collected (see Figure 2). The blank showed that not all of the water and carbon dioxide peaks were subtracted by the software, but that the peaks were relatively small. The background showed what was taken out of future samples by the software, while the blank sample indicated what was still shown. The background factored out most instrumental and atmospheric elements, but a small percent transmittance sometimes remained. Results from the four kernels grown under control conditions are seen in Figure 3. The number and letter combination symbolizes the treatment the kernels were grown in. A different letter means the kernels are from different cobs. The kernel 510 G had a strong inverted peak around 1000 cm⁻¹. There was also a slight dip around 3250 cm⁻¹, representing an O-H stretch. This was most likely moisture due to the shape of the peak (Quintás et al., 2008). The kernel 510 B also had an inverted peak around 1000 cm⁻¹ with a very small dip around 3250 cm⁻¹. Background was measured after every sample, and therefore, air humidity from the chamber was removed from these results. The strongest inverted peak around 1000 cm⁻¹ belonged to 510 H, but it also produced inverted peaks around 1700 cm⁻¹ and 2900 cm⁻¹. These inverted peaks, along with the dip around 3250 cm⁻¹ are atmospheric peaks (Quintás et al., 2008). Less reflectance and minimal background peaks were collected from 510 E.

Three kernels from a low nitrogen treatment produced spectra with inverted peaks (see Figure 4). For the 510 H kernel there was a peak around 1000 cm⁻¹, which was similar to the control results. Weak peaks appeared around 1700 cm⁻¹, 2900 cm⁻¹, and 3250 cm⁻¹, all of which are from the atmosphere (Quintás et al., 2008). The 510 E kernel produced a stronger inverted peak at 1000 cm⁻¹. Lastly, the 510 G kernel produced less transmittance throughout the spectrum. To compare the two treatments, the peaks were labeled with the OMNIC software.

Multivariate analyses were completed to determine if the peak heights and percent transmittance were significantly different. A discriminant model was created for all the measured peak values. The smallest p-value observed was 0.06351 which was not significant; the p-value was tested at the 95% confidence level. To compare the peak amounts within the starch region, a Wilcoxon test was completed. The test produced a Chi-square value of 0.2888. After the starch values were corrected based on the value at 2250 cm⁻¹ (Table 1), the power test resulted in 19. This indicated that nineteen samples would need to be analyzed to get statistically different results provided the differences were due to differences reflected in the population of all samples. This number is useful for future research with these kernels to provide a larger sample size and to determine if there is significance in the results. The adjusted starch peaks comparison is shown in Figure 5. Only one peak value from the low nitrogen samples was as low as those from the high-nitrogen samples, thus making our estimate of power large. It is unclear what reduced the power of our comparison.

DISCUSSION

The low nitrogen kernels did not differ from the control kernels, revealing that
Figure 1. Background collected from the instrument to factor out atmospheric carbon dioxide and water.

Figure 2. Results from a blank sample, y-axis percent transmittance and x-axis wavenumber, cm$^{-1}$.
Table 1. Starch region wavenumber values after adjustment for the value at 2250 cm\(^{-1}\).

Kernels 510 B, E, G, and H were grown in regular levels of nitrogen while kernels 516 E, G, and H had a low nitrogen environment.
the Mo276 genotype may be more resistant to extreme conditions. Whole kernels could not be analyzed using the ATR FT-IR. This was due to the hard, outer shell of the kernel (Zuelsdorf, 2016). The single beam was not strong enough to penetrate the shell and receive signal. Previous studies have been successful with maize flour. In the most comparable study, the setup was extremely similar except a diamond single beam was used (Kuhnen et al., 2010).

Starch signals were present from 800 to 1200 cm\(^{-1}\) (Kuhnen et al., 2010). All kernels had an inverted peak around either 997 or 1013 cm\(^{-1}\), which were not present in the background. Therefore, these signals were most likely caused by starch. Based on a previous study, the peak shifts due to water amounts present in the kernel. Water can lead to a shift from 1022 cm\(^{-1}\) to 1015 cm\(^{-1}\). The influence of water can lead to missing peaks in regions peaks would normally be seen (Kuhnen et al., 2010). Beer’s law shows that a higher absorbance occurs at higher concentrations; therefore, since transmittance and absorbance are inversely related, a lower transmittance will correspond to a higher concentration. A signal that appeared in all kernels was a peak around 1641 cm\(^{-1}\). Protein can appear in maize around this region, from 1550-1650 cm\(^{-1}\), but in low amounts, which would result in weak peaks (Kuhnen et al., 2010).

One control kernel, H, exhibited several other peaks, some much stronger than other samples. The peaks may have showed the presence of lipids, which appear at 2924, 2854, and 1740 cm\(^{-1}\) (Kuhnen et al., 2010). There was an inverted peak in this area in a few samples, though the peak selector did not detect some of them. At 2924 cm\(^{-1}\), a weak peak appeared. Since lipid only makes up 5% of maize, and can potentially be decreased with low levels of nitrogen, that may be the cause of these peaks. However, the background picked up a signal at 2921.6 cm\(^{-1}\). Alternatively, the ZnSe crystal may have shifted during transfer of the ground kernel onto the plate. This may also be the source of some of these peaks. Seed weight can impact the composition of the kernel, therefore, for future studies it will be necessary to weigh the kernels and compare them to the results (Baye et al., 2006).

Based on the power test, it is necessary to collect more samples to determine if nitrogen has an effect. Another test that can be completed is to look at the peak shape rather than the height to determine if there is difference there. It appears that starch may be lower in the low nitrogen treatment (see Figure 5); however, at least nineteen samples would need to be collected to determine if this is true. These results show that the Mo276 genotype kernel composition is not strongly affected by growth of the plants under nitrogen deprivation, but a larger study must be completed to determine the level of significance. For this study the small sample size was appropriate for my design and data analysis, in order to produce these preliminary results (Norman and Streiner, 2014). This genotype is thus a good candidate for further trials of stress resistance in maize breeding programs.
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Perceptions of Social Mobility in the Country of the Year: an examination of globalization and consumerism in Uruguay

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ABSTRACT
Western influence around the globe is not only apparent in economic or trade spheres. The cultural, social, and ideological influence of nations like the United States on individuals in societies near and far is growing, spurring interesting questions about the fluidity of social thought and collective perception. Do individual outlooks become more global in perspective as large-scale governmental and economic changes occur? If so, what are the social implications of changing individual ideologies on immediate geographical contexts and larger global trends? This paper explores this broad intersection, via quantitative and qualitative methods, by specifically examining social mobility perceptions, individual definitions of success, and consumerism trends in Uruguay. By accounting for the social dimension of more palpable economic and political globalizing forces, this paper investigates the permeation of ideology and lifestyle in Uruguayan society following the expansion of Western businesses and the intermingling of consumerism, materialism, and perceptions of social mobility—both in Uruguay and the United States.

Western influence around the globe is not only apparent in economic or trade spheres. The cultural, social, and ideological influence of nations like the United States on individuals in societies near and far is growing, too, spurring interesting questions about the fluidity of social thought and collective perception. For instance, do individual outlooks globalize alongside overarching governmental and economic changes? If so, what are the social implications of changing individual ideologies on immediate geographical contexts as well as larger global trends?

Social mobility—the movement (or capability for movement) of individuals and households between a society’s social and economic tiers—is at the core of one’s social, economic, and educational trajectory in life. Thus, an individual’s perception of social mobility is immensely consequential to how the individual regards larger institutions and society itself.

Often deemed the most European country in South America and called “The Country of the Year” in 2013 by news magazine The Economist, Uruguay is a prime example of globalization in a cultural and social structural sense. Since the end of civil-military
rule in 1985, Uruguay has re-entered the global marketplace as the important exporter of agricultural products that it formerly was. In addition to beef, dairy, and soybean exportation, Uruguay is South America’s first producer of software. Today, a walk through the more commercial avenues of Montevideo—Uruguay’s coastal capital and home to roughly half of the nation’s three million inhabitants—inevitably includes a McDonald’s sighting, where one can likely order in Spanish or English. A swath of consumer products and with it, opportunity for wealth, has made it to Uruguay. This paper explores this broad intersection by specifically examining social mobility perceptions, individual definitions of success, and consumerism trends in Uruguay. By accounting for the social dimension of more palpable economic and political globalizing forces, this paper investigates the permeation of ideology and lifestyle in Uruguayan society following the expansion of Western businesses. In addition to the exportation of business practices and new products, does underlying ideology travel to new markets, too? Can the “American Dream” be exported?

**LITERATURE REVIEW**

**Perceptions of Social Mobility**

Beliefs, perceptions, and opinions about meritocracy and the fluidity of social mobility are fundamentally important to the ways individuals understand and experience their participation in the society in which they live. Social scientists have suggested that individual and group perceptions of social mobility and meritocracy have an impact on an array of social phenomena, ranging from judgement of social injustice to justification of social realities (Reynolds and He 2014).

This review of literature frames measurable realities of social mobility in addition to perceptions of these realities. While this paper is ultimately concerned with the comparative study of social mobility perceptions in Uruguay and the United States—and the impact of these perceptions in Uruguayan society—consideration of actual mobility trends gives additional context for this paper’s discussion.

More than a projection of personal ideals, one’s perception of social mobility fluidity and meritocracy often co-exists with perceptions and opinions of inequality at a macro level. In the United States, the belief that upward social mobility is fluid and achieved through hard work is often referred to as the “American Dream,” and has been shown to serve as a justification of the status quo (Ledgerwood et al. 2011, McCoy and Major 2007, Kluegel and Smith 1986). The belief in social mobility and meritocracy manifests itself in the legitimation of status differences, as a byproduct of work ethic discrepancies or as a justification of increasing income inequality. Additionally, in a comparative international analysis, Hadler found that individuals’ perceptions of inequality vary significantly even between Western nations. For instance, survey respondents in Sweden labeled income difference between “chairman” and “unskilled worker” unequal when the ratio, in terms of salary difference, was greater than three to one while US respondents didn’t label the same scenario unequal until the ratio surpassed nine to one. This gap was largely attributed to an ideological difference in regards to social mobility and achievement standards (Hadler 2005). As Kluegel and Smith have argued, dominant stratification ideology, shared by seemingly all members of a given society, dictates a certain idea of systemic and individual inequality through the social and cultural narratives it conveys. In the United States, the authors conclude, an individualistic explanation of inequality overwhelmingly exists, rooted in meritocratic ideals and a rejection of larger structural causes (Kluegel & Smith 1986).

As Max Weber theorized, maintaining the status quo is a central endeavour of many political systems, including those marked by an attachment to tradition—such as monarchies, for instance—or to the law, as in most Western democracies. For Weber, both traditional and legal authorities are organized
around continuity—and therefore a reluctance to change—albeit for different reasons. System-justification theory purports that political conservatives are more likely to defend current social realities, deeming them just and fair in an attempt to maintain the status quo (Jost, Banaji, & Nosek 2004). Similarly, social-dominance theory contends that people often defend the existence of social stratification by rationalizing and ideologically legitimizing differing life outcomes between groups (Sidanius & Pratto 2001). Both theories emphasize the foundational belief in fluid social mobility and meritocratic values, explaining inequality by highlighting the importance of individual action like work ethic and personal sociability rather than larger systemic constraints like discrimination.

Beyond social system justification, Thompson and Bobo found that social values and meritocratic ideology additionally help shape crime attributions. Groups that heavily stress the role of individual behavior, both economic and meritocratic, attribute greater significance to discrete action and less to any structural factors when considering the roots of criminal activity (Thompson & Bobo 2011).

Perception of social mobility may also impact health outcomes. Adhering to the dominant "American Dream" ideology, in which social mobility malleability and life outcomes are assigned individual responsibility, leaves millions of Americans—largely racial and ethnic minorities—at risk of psychic and physical stress if hard work over many years does not culminate in significantly higher social status or income (Kwate & Meyer 2010).

However strong and ostensibly culturally-imbbedded sentiments of social mobility seem to be, confidence in this belief system appears to be declining in the United States. A 2013 gallup poll found that “52% of Americans agreed that there is plenty of opportunity for the average person to get ahead in life, down from 81% a mere 15 years earlier, and the lowest level in over six decades” (Dugan and Newport 2013). In addition, significantly fewer Americans are hopeful today that their children’s standard of living will surpass their own (Pew Research Center Report, 2012).

Chambers found that while there is a demonstrable decline in widespread belief in social mobility fluidity within the US, especially since the 2008 recession, actual social mobility data suggests there has been little change over the past 20 years (Chambers 2015). Contrary to popular belief, intergenerational social mobility was found to be quite stagnant in recent history (Chetty, Hendren, Kline, Saez, & Turner 2014). Chambers additionally found this decline in perception of upward social mobility to follow and divide along political lines. Skewed by political ideology, liberals were found to overestimate the economic stickiness of lower class mobility while conservatives underestimated upper class retention. In all cases, however, both liberals and conservatives underestimated the likelihood of social mobility in US society (Chambers 2015).

Even with consideration of this decline, belief in meritocracy and fluid social mobility is still significantly stronger and more ubiquitous in the United States than all other wealthy nations, according to a 2008 Brookings Institute paper (Isaacs et. al. 2008, Reynolds and He 2014). While the US and the United Kingdom have the lowest social mobility levels among Western nations, the belief in social mobility was found to be the strongest (Gould 2012). Using an intergenerational earnings elasticity index—comparing the relationship between father and son earnings over a lifetime—50% (or an index of .5) of a father’s earnings are passed onto sons in the United States while high mobility nations like Finland or Denmark have indexes less than 20% (or .2). With a score of .5, an average of six generations would need to pass in order for family economic advantage to disappear in the United States, assuming current trends hold (Isaacs et. al. 2008). In general, the lower the index, the more fluid a nation’s social mobility is.

During this notable decline in confidence in the United States, these same perceptions seem to be increasingly optimistic in much
of Latin America. Using data from the annual Latinobarometer opinion survey which encompasses 17 countries, Gavira found that 55% of respondents answered that they face better opportunities than their parents did a generation before (Gavira 2010). Additionally, 58% of respondents felt that their children would have better opportunities in the future than they currently have (Gavira 2007). There are little published data of perceptions of social mobility specific to Uruguay, but Azevedo and Bouillon indicate a general optimistic perception of social mobility and future opportunities in Latin America, including Uruguay (Azevedo & Bouillon 2010).

Though actual social mobility patterns vary tremendously in South America, no nation on the continent has mobility more fluid than the United States (Isaacs et. al. 2008). In fact, Gavira and Dahan found the intergenerational elasticity index to be anywhere from 1.8 to 3 times greater in Latin American countries in comparison to the United States (Gavira 2001). Among South American countries, Chile, Argentina, and Uruguay have the most fluid social mobility with intergenerational elasticity indexes between .52 and .60 (Azevedo & Bouillon 2010), meaning between 52% and 60% of fathers’ earnings are passed onto sons. While neighbors Brazil and Uruguay have similar long-term growth rates and GDP per capita, Uruguay is much more socially mobile. Instead, Uruguay is more similar to its other neighbor, Argentina, in growth as well as different measurements of social mobility fluidity (Andersen 2000). In addition to having one of the lowest income elasticity indexes in South America, Uruguay also has the lowest income inequality of all Latin American countries with a GINI coefficient of about 41%, which is approximately the same as the United States (Bukstein & Gandelman 2014). Additionally, Uruguay has the highest urbanization rate on the continent, a factor associated with the nation’s industrialization, changing economic landscape, and relatively fluid social mobility and low inequality (Azevedo & Bouillon 2010).

The intergenerational educational mobility index—a model that illustrates the relationship between a parent and child’s educational attainment—is another important indicator of social mobility fluidity. Conconi et. al. found a reduction in the estimated mobility index, as a result of a decline in educational mobility for Uruguay over the past decade—a reality that influences social mobility (Conconi 2008). Over the same time, inequality has also grown; compared to its early 1990s GINI coefficient markers, Uruguay’s income inequality has slightly grown as a result of regional macroeconomic crises (Gasparini 2011). However, according to Bukstein and Gandelman (2014), this decline in opportunity seems to be met with greater levels of optimism about social and economic opportunity. In Figure 1 below, intergenerational income elasticities are compared between an array of countries, including the United States and Uruguay, where lower ratios indicate greater fluidity in social mobility.

**Consumerism**

Paralleling this increasingly strong belief in social mobility fluidity and decreasing actual mobility is a surge in consumerism and the availability of new products. In Uruguay, this was met with a staunchly outspoken and internationally-known opponent, former Uruguayan president Jose Mujica. Highlighted in a 2015 New Republic article, Montevideo has seen a steep rise in availability of consumer products and fiercely growing consumptive behavior. As one Uruguayan journalist complained, Audi dealerships and smartphone outlets are popping up everywhere, often to the detriment of local business. In front of the entire United Nations General Assembly, Mujica proclaimed in his native Spanish, “we have sacrificed the old immaterial gods and now we are occupying the temple of the market god.” Shedding light on changes in his own country, Mujica continued, “this god organizes our economy, our politics, our habits, our lives. It seems we have been born only to consume” (Fairbanks 2015).
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**Figure 1:** Intergenerational Income Elasticity International Comparison

South America has long played a significant role in global consumption trends. With the advent of major international advertisement in the early 20th century alongside the emergence of global industrialization and factory line production in the United States, marketing campaigns first appeared in Latin America following the United States. Manifesting itself in commercial radio, television, and movie production, U.S. corporate interests expanded even more zealously into Latin America than Europe in some cases. For instance, as late as the 1960s, Argentina had more television sets per capita than France (Woodard 2012).

After much regional civil conflict and military rule in the 1970s and 1980s, this consumptive market behavior was again rekindled in part by the creation of Mercado Comun del Sur, or Common Market of the South (MERCOSUR) in 1991. Created to further stimulate the economies of Argentina, Brazil, Paraguay, and Uruguay, MERCOSUR initially sought more ubiquitous regional free trade and exchange of goods and currency as well as the attraction of foreign investment to the region (Munck 2001).

In the United States, a similar trend toward greater consumption and materialism is widely perceived to exist, as well. Starting in 1968, each year UCLA has asked college freshman “what are your most important personal objectives?”. In the first year of the study, only 41% listed being “well off financially” as very important while 75% of students deemed developing a “meaningful philosophy of life” very important. Over the next two decades, the answers gradually flipped. By 1998, 74% marked being “well off financially” as very important while only 41% of respondents marked the same for developing a “meaningful philosophy of life” (Pryor et. al. 2007). This doesn’t necessarily mean that college students are intrinsically more materialistic now than before, however. Economic stakes have immensely changed and the distance between socioeconomic rungs is drastically greater now than in the 1960s. That is, the monetary penalty has grown for choosing a career of interest and passion over a more lucrative and financially stable career. The income difference between a teacher and an investment banker, for example, is far greater now than in the 1960s and 1970s (Reich 2002).

Consumerism is also inextricably linked to cultural and social realities, serving as a conduit for macro- and micro-level exploration in Social Sciences.
communication. In 1979, Mary Douglas wrote:

Instead of supposing that goods are primarily needed for subsistence plus competitive display, let us assume that they are needed for making visible and stable the categories of culture...it is apparent that the goods have another important use: they also make and maintain social relationships.

By arguing that consumption is a means of stabilizing cultural categories and social relationships (e.g. wedding rings), Douglas highlights the important relationship between cultural and consumptive trends and realities (Douglas & Isherwood 1979).

In the midst of the 18th century industrial revolution, urbanization rates spiked. As droves of Western Europeans headed to industrialized cities, leaving behind more agrarian societies, social mobility fluidity increased as the opportunity for employment became more prevalent. As historian Peter Stearns theorized, this increase in social mobility helped contribute to a drastic rise in consumerism, or the “consumer revolution” as Stearns dubbed it. With an increase in social mobility fluidity as well as greater individualism and a blurring of social class lines, Western European societies turned to consumerism to differentiate socio-economic realities, through means such as clothing and home decor. In this sense, social mobility realities and urbanization impact consumerism trends (Stearns 2006).

For Uruguay, a nation with the highest urbanization rate of all South American nations and one of the lowest social mobility elasticity indexes, extrapolation of Stearns’ theory proves relevant and interesting. This paper explores the role of materialism—defined here as the extent to which one views the acquisition of material possessions as both inherently important and emblematic of success—within this consumer market boom as a link between perception of consumerism and perception of social mobility. In essence, if individuals increasingly consider the acquisition of material goods to be a marker of social and economic achievement and there is increasingly greater availability of cheaper and more diversified material goods, does perception of social mobility become more and more fluid? As people are able to acquire more inexpensive goods that they increasingly perceive to be measures of success, do they consequently view social mobility as more fair and attainable, regardless of measurable social realities?

**METHODS**

In order to capture both the quantitative and qualitative nuances of social mobility perception and consumerism, this paper employs a mixed-methods approach involving two quantitative surveys in the United States and Uruguay and nine semi-structured interviews in Montevideo, Uruguay. This research project was reviewed and exempted by the University of North Carolina at Greensboro Institutional Review Board Office of Research Integrity in the spring of 2015.

In May 2015, a ten question survey using a five-point Likert scale for all non-demographic questions was sent to an array of professors at Universidad Catolica del Uruguay (UCU) to send on to their respective students (convenience sampling). The questions focused on perceptions of social mobility in Uruguay—both its importance and reality—opinions of Western influence in Uruguayan culture and economics, and the importance of consumerism in Uruguayan society. All questions, instructions, and exchanges were conducted in Spanish. The survey was closed in September 2015. There were a total of 170 respondents.

In September 2015, a similar ten question survey translated to English and reworded to fit the respondents’ context was sent via email to a random pool of 3,750 UNCG undergraduate students, selected randomly from a master list of all undergraduate email addresses. This survey, like its Uruguayan counterpart, asked students to express their perceptions of social mobility in the United States, the importance of consumerism, and the influence of Western nations like the United States in cultural and economic realities of South America.
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American countries. The survey was closed in October 2015. With a sample of 534 respondents, the survey’s response rate was 14%.

The target demographic for both surveys was undergraduate university students in order to compare perceptions of individuals that are largely on the precipice of entering the workforce and thus, less likely to be biased by individual occupational events—whether positive or negative. While not representative of society at large, student perceptions provide interesting insight into mentalities that will soon make up a significant segment of the working population. For analysis, both Levene’s Test for Equality of Variances and Two-tailed t-tests for Equality of Means were used in order to test for significance in difference between both survey groups, regarding the distribution as well as the mean of responses.

To provide greater depth and context to the quantitative survey responses, nine semi-structured interviews were conducted in Uruguay, as well. By allowing the interviewee to expand and verbalize sentiments concerning social mobility and consumerism trends over the past 15-20 years in Uruguay, this paper’s topic was further explored into the non-quantifiable, subjective side of perceptions. Without substantial longitudinal data documenting perceptions of social mobility in Uruguay, the interviews were conducted in order to compare current student sentiments to those in the past (for further discussion, see Discussion below).

The interview participants were recruited through academic contacts at UCU and either interviewed in-person or via email, if scheduling a meeting proved too difficult given the time constraints of the project. The interviews were all conducted in Spanish and later transcribed and translated into English for coding and analysis. While diversity in socio-economic status, occupation, upbringing, and numerous other variables was sought, the snowball sampling technique utilized did not allow for an ideal level of diversity and randomness in the recruitment process. Most interview participants had a graduate level education, in careers ranging from architecture to academia.

RESULTS

Quantitative Findings

Table 1 displays demographic variable averages for respondents from both surveys. It was thought that one’s educational attainment relative to their parents’/caretakers’ might skew perceptions of social mobility importance and fluidity. However, the evident similarity between rates of first generation university students indicates that any significant difference between perceptions is likely a result of other factors.

Table 2 contains the results from both surveys concerning perceptions of social mobility in the participants’ respective national contexts. The text in the left column represents the response selected, in a yes or no for mat. There is apparent similarity between US and Uruguayan responses. The US responses mirror those of most prior research, falling in between the findings of Dugan and Newport (2013) and Reynolds and He (2014) with 60% of respondents believing upward social mobility to be probable in their own lives. Given the comparatively strong optimism of US perceptions found in the literature review,

<table>
<thead>
<tr>
<th></th>
<th>US (n=534)</th>
<th>Uruguay (n=170)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Age</td>
<td>22.3</td>
<td>24.2</td>
</tr>
<tr>
<td>First generation university student</td>
<td>180 (34%)</td>
<td>62 (36%)</td>
</tr>
</tbody>
</table>

Table 1: Relevant Respondent Demographic Information
the immense similarity of Uruguayan responses to those of the US survey is notable. Independent t-tests were used to test for differences in student responses in the US and student responses in Uruguay. However, there were no significant differences in students’ perceptions; that is, the US and Uruguayan responses regarding the existence of social mobility fluidity, importance of social mobility, and optimism for social mobility in the next 5 years were similar. However, using a 90% confidence interval, there was a significant difference between the mean responses when grouping by country for the importance given to social mobility fluidity by respondents (p-value of .010). This difference is further elaborated in Table 3 which provides a cross-tabulation of perceived social mobility importance in order to further illustrate the differences between respondent groups. Additionally, there was a significant difference found between the distributions of responses pertaining to the 20-year year social mobility outlook. This difference is further elaborated in Table 4, a cross-tabulation comparison of 20-year outlooks of personal social mobility.

However, when the analysis was expanded to include all of the five Likert answer choices, a notable difference between “Extremely Important” responses appears—partly explaining the significant difference found between the two groups. While both groups generally indicated that social mobility was important, 26% of US respondents chose the strongest response available while...
Given the well-documented confidence of US perceptions, it is the similarity not the difference that is most striking from these findings. In Table 5, responses to the two survey questions regarding perceptions of materialism and the importance of consumerism as a marker of success are presented; the text in the left column represents the “yes” response in the survey. Across generations, materialism and consumerism seem to jointly exist as important social realities, used to exude and affirm both social and financial success in Uruguay, even more so than in the United States. As a nation rife with mass production and tailored marketing campaigns, the United States is widely regarded as the prime example of materialism, the pinnacle of consumption—with only 5% of the world’s population, the United States consumes close to a quarter of the world’s resources (Rühl 2008).

Table 4: Cross-tabulation of 20-year Outlook

<table>
<thead>
<tr>
<th>In 20 years, do you see yourself as better off financially than you are now?</th>
<th>Definitely yes</th>
<th>Probably yes</th>
<th>Probably not</th>
<th>Definitely not</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>396 (74.2%)</td>
<td>128 (24.0%)</td>
<td>7 (1.3%)</td>
<td>3 (0.6%)</td>
<td>534 (100%)</td>
</tr>
<tr>
<td>Uruguay</td>
<td>107 (64.1%)</td>
<td>54 (32.3%)</td>
<td>6 (3.6%)</td>
<td>0 (0%)</td>
<td>167 (100%)</td>
</tr>
<tr>
<td>Total</td>
<td>503 (71.8%)</td>
<td>182 (26.0%)</td>
<td>13 (1.9%)</td>
<td>3 (0.4%)</td>
<td>701 (100%)</td>
</tr>
</tbody>
</table>

Table 5: Materialism/Consumerism Responses

<table>
<thead>
<tr>
<th>Materialism is important, a sign of success for respondents</th>
<th>US (n=534)</th>
<th>Uruguay (n=170)</th>
</tr>
</thead>
<tbody>
<tr>
<td>268 (50%)</td>
<td>103 (60%)</td>
<td></td>
</tr>
<tr>
<td>Materialism is currently important, a sign of success for parents/guardians</td>
<td>237 (45%)</td>
<td>98 (58%)</td>
</tr>
</tbody>
</table>

only 9% of Uruguayan students did. This perhaps indicates a certain zeal in US outlooks of social mobility and its importance that is not echoed in Uruguayan society.

Again, the significant difference found in the response variance of Table 4 seems to lie in the strength of the affirmative answer given. While 74.2% of the US respondents answered “Definitely Yes” when asked if they saw themselves improving upon their current social and economic status, 64.1% of Uruguayan respondents answered “Definitely Yes.” Instead, more Uruguayans answered “Probably Yes” or “Probably Not.” The US respondents seem to have answered with greater confidence in their prospects. Looking past this difference in strength of the given affirmative answer, the more surprising result is perhaps the finding that Uruguayan and US students generally have similar outlooks on social mobility likelihood and importance. Given the well-documented confidence of US perceptions, it is the similarity not the difference that is most striking from these findings.

In Table 5, responses to the two survey questions regarding perceptions of materialism and the importance of consumerism as a marker of success are presented; the text in the left column represents the “yes” response in the survey. Across generations, materialism and consumerism seem to jointly exist as important social realities, used to exude and affirm both social and financial success in Uruguay, even more so than in the United States. As a nation rife with mass production and tailored marketing campaigns, the United States is widely regarded as the prime example of materialism, the pinnacle of consumption—with only 5% of the world’s population, the United States consumes close to a quarter of the world’s resources (Rühl 2008).
However, these data confer an alternative reality, at least in terms of perceptions. While about half of US survey participants regarded material possessions as both important and a sign of success, 60% of Uruguayan respondents affirmed the significance and importance of materialism.

In summary, there were significant differences between US and Uruguayan respondents regarding perceptions of materialism. Specifically, Uruguayan participants more frequently deemed materialism to be important and emblematic of success, both personally and for their own parents or guardians.

Table 6 highlights an interesting divide between US and Uruguayan responses when it comes to perceiving the influence of Western nations in South American countries like Uruguay. Perhaps most interesting is the finding that over three-fourths of Uruguayan respondents believe Western influence in the realm. The findings indicate a difference between the degree of affirmation in responses among the cohorts. Compared to the 14% of US respondents who believe the West to have “an extreme amount” of influence in South American social and cultural affairs, almost 36% of Uruguayan respondents felt the same—about 2.5 times more of Uruguayan culture and social trends to be strong or extreme.

**Qualitative Findings**

Semi-structured interviews were utilized to better contextualize the quantitative data collection, providing greater depth and space for individual nuance. Only conducted in Uruguay with adults older than 35, they provided vital insight into a changing Uruguayan economic and social landscape. While the surveys provided a momentary snapshot of perception in today’s society, the interviews placed the quantitative data in a larger, more fluid context—creating a more protracted dimension to the data collection, since there were no available longitudinal data sets regarding perception of social mobility in Uruguay.

Table 7 shows the principal topics of each interview and quantifies each respondent

<table>
<thead>
<tr>
<th>US (n=534)</th>
<th>Uruguay (n=170)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes, the West has strong or extreme influence in Uruguayan politics*</td>
<td>263 (49%)</td>
</tr>
<tr>
<td>Yes, the West has strong or extreme influence in Uruguayan culture/social trends*</td>
<td>269 (51%)</td>
</tr>
</tbody>
</table>

*US participants were asked about South American politics, culture, and social trends with Uruguay as an example country. Uruguayan participants were asked specifically about Uruguay.

**Table 6: Perceptions of Western Influence Responses**

<table>
<thead>
<tr>
<th>Change in Mobility (n=9)</th>
<th>More/Less Likely to be Mobile (n=9)</th>
<th>Change in Consumerism (n=9)</th>
<th>Difference in Product Availability (n=9)</th>
<th>(total responses)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes/More</td>
<td>9</td>
<td>8*</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>No/Less</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>(total)</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
</tr>
</tbody>
</table>

*2 respondents noted that the stickiness in the upper echelons of society is still as strong as it used to be a couple of decades ago, but that there is now greater mobility in the middle class

**Table 7: Interview Responses, Coded**
answer in order to provide a brief, generalized summary of the nine interviews. Each interviewee mentioned a distinct change in both social mobility fluidity and consumerism, with trends progressing toward greater social mobility, specifically upward social mobility, and a generally more consumptive society and culture in the past 15 to 20 years.

All but one interview participant indicated that they believe that they now have a greater chance of upward mobility than they did a couple of decades ago. For instance, one participant supplied anecdotal evidence of a friend who found stable work as a university custodian and was able to take the Uruguayan equivalent of a GED course in order to earn a secondary school diploma and later, a higher paying job. This participant further elaborated on the academic success of their friend’s children and their consequent hopeful futures. A story like this wouldn’t have been possible two or three decades ago, the respondent concluded.

As another respondent elucidated, “I think that before, there was a distinct and divided high and low class. Now the middle class has grown and more people are in that class.” A university professor elaborated on this change in social mobility, saying: “I think the social fringes have more opportunities and mobility...but it is very difficult to have inclusion and openness in higher classes so [the people on the social fringes] can pass them.”

A different interview participant framed the changed reality as something more psychological than physical, particularly in the upper class of Uruguayan society, stating: in today’s society, there are more demanding and continuous needs for personal improvement just to maintain the status of each person. This extra effort has made it difficult to achieve success—which increasingly demands time, quality and costs, and this leads to frustration as people return to the point of origin. This is the phenomenon of a stratified society where there is little to no social mobility to the uppermost class.

The same individual further frames this widespread change in perception of social mobility in discussion of changing consumerism trends:

Consumerism has had an exponential change in qualitative and quantitative terms. Consumerism covers more of society, including people from social positions that had not previously had possibilities to access even certain staples. Many people now borrow excessively to get products which they do not need, but that are fashionable or whimsical.

The idea that social mobility is now more fluid for younger generations in the middle and lower echelons of society, but still stagnant in the upper tiers of social and economic life was voiced twice. However, it was routinely noted that the sudden spike in product availability and consumptive behavior was caste-free. That is, all social classes and demographics had opportunities to consume a new array of products, in part due to the availability of credit cards and store payment plans. This increase in product availability and consumeristic behavior was described by two respondents as a race, with one participant stating:

There are clearly differences, depending on social class, but still...with the variety of products and ease to buy...all classes are in the race of consumerism

Another participant added:

It has changed a lot. There is a race to consumerism, ‘I must have it,’ but we do not need to. The change has also been because of the financial possibilities for [people] to purchase the products with credit cards, loans, etcetera.

Another interviewee framed material consumption in Uruguayan society as expression, speaking to Douglass’ idea of consumerism as a means of “competitive display,” saying:

It has been more accelerated in recent years... There is much more variety of products and... varieties of quality or attributes to differentiate each other to reach a certain target social level, creating the necessity of consumption.

More than any other topic broached in the interviews, a resounding “yes” followed all questions concerning changes in consumerism and access to an increasingly materialistic lifestyle in Uruguay. As one participant reflected:
I now have more access to more things than when I was a child, for example. There are now many options and kinds of sales, like online shopping, credit cards. There is a definite trend towards consumerism...today there is more availability and access to consumer products. It's hard to want something and not get it.

Summarizing many of these perspectives of both social mobility and consumerism, one interviewee concluded by noting that “...Uruguayans now have more opportunities and freedoms not previously had...the country is opened to the world and we have assimilated its processes.”

DISCUSSION

In Consumerism in World History, Peter Stearns poignantly notes:

what is sometimes called “Westernization” involves the spread of consumer behaviors, often under the urgent leadership of European and United States commercial companies. By 2000 Western influence in the world at large rested on consumer standards more than anything else, outlasting military and colonial predominance (Stearns 2006, p. ix).

It is from this caption of the West’s influence in both consumerism and consumption trends worldwide that many of this paper’s conclusory points rise.

Considering the anomalous strength of the belief in social mobility fluidity amongst the US population in reference to European nations, the staggering similarity with which the Uruguayan social mobility survey results compare to its US counterpart was a notable surprise. Additionally, the similar responses concerning perception and importance of materialism as an avenue of both exuding and attaining success between both surveys and participant pools are significant findings. However, it is the anecdotal findings pulled from the nine interviews that provided critical context for the survey responses, speaking not only to similarity between perceptions of US and Uruguayan university students, but a veritable shift in Uruguayan perceptions—bending over time towards current US modalities.

With high levels of consumerism and perceptions of social mobility coinciding with decreasing social mobility and income equality in Uruguay, as suggested by the literature and this study’s findings, trends seem to be increasingly mirroring realities in the United States. That is, while actual rates of upward social mobility and income inequality lag behind in international comparison, confidence in social mobility and consumptive habits are comparably high. Whether these trends in Uruguay and the US are paralleling each other or merely meeting as they move in opposite directions, however, is ultimately unknowable given this paper’s cross-sectional nature.

As McCoy and Major demonstrated in their 2007 study, an increase in the importance given to social mobility as well as a greater confidence in social mobility fluidity result in a justification of inequality and often, in personal legitimation of systemic realities with a de-emphasis on the role of discrimination in different social statuses (McCoy and Major 2007). This finding is important to note when considering the increasing aforementioned inequality and stratification in both the US and Uruguay.

Extrapolating from the consumer theories of anthropologist Mary Douglas, a change in consumer trends indicates a change in cultural motifs, cultural categories, and cultural communication (Douglas & Isherwood 1979). Thus, Uruguay has not only undergone an economic or social shift, it has undergone and is in the midst of a cultural shift, as well.

Perhaps most interesting, however, is the role of perceptions of social mobility fluidity in ostensibly molding consumptive trends, and vice versa, the influence of consumerism in guiding perceptions of social mobility. As suggested by this paper’s findings, both perceptions of social mobility fluidity and consumptive behavior have seemingly increased over the past two decades in Uruguay. Rather than existing and changing independently, they shape each other and consequently, society at large. Personal definitions of success as well as the means of displaying and
internalizing success have increasingly become materialistic. Thus, as the pursuit of success is more and more deemed a component of consumerism and as social mobility is seen as fluid to an increasing extent, perhaps partially due to the influx of cheap goods in a consumeristic society, a cycle is formed. These two social modalities appear to exist in a positive feedback loop; over time, an increase in one correlates with an increase in the other (see Figure 2).

Following the findings of McCoy and Major in addition to numerous other papers (e.g. Ledgerwood et al. 2011, Kluegel and Smith 1986, Sidanius & Pratto 2001, Thompson and Bobo 2011, Kwate & Meyer 2010), it can be argued that consumerism masks actual social modalities, like discrimination and social inequality. If perceptions of the state of meritocracy and social mobility alter one’s understanding and explanation of social realities, consumerism trends likely do, as well. One’s obedience to macro social forces, norms, and institutional expectations seems partially dependent on one’s individual optimism for success; essentially, one likely buys into a social system that claims to reward one’s effort and talent when it seems to be true. As individual definitions of success increasingly turn materialistic while product availability becomes more and more diversified and inexpensive, upward social mobility perhaps seems more fluid and possible. This reality has the potential to blind, via material satiation, an increasingly unequal and stagnant society with the dangling, perhaps illusionary, carrot of achievable prosperity, fluid social mobility, and attainable success-affirming consumption. As long as individuals perceive their reality to be fair and meritocratic, it will in a sense be fair and meritocratic—regardless of empirical evidence to the contrary.

The encompassing social effects of increased consumerism and social mobility perceptions in society are well-entrenched in the US social fabric. For the nation of Uruguay, however, this is novel change. Using perspectives from these trends in the US gives insight both into the present and potentially, the future of Uruguayan society—namely regarding perceptions of increasing inequality, upward social mobility, and the expression of socio-economic success.

When products find new markets, ideas do too. Aside from a change in the availability of products and subsequent shift in lifestyle, globalization brings about a change in ideology and social perception. Drastic change in materialism and product availability has swept through Uruguay in the past two decades. Paralleling this material and consumptive change has been a notable change in students’ perception of social mobility fluidity and perceptions of materialism and success. The inertia of globalization has reached Uruguay—socially as well as economically—including the exportation of the “American Dream” and its accompanying meritocratic optimism and materialistic behavior.

In light of the potential for social complicity and ranging bias rooted in changing perceptions of social mobility, there exists a need for greater education and discussion of measurable socio-economic trends in all political and social spheres—to emphasize empiricism and the gap between perception and reality. Furthermore, recognizing that the introduction of product, business model, and lifestyle also involves potential shifts in collective perception and outlook is an important consideration in any evaluation of globalization and its myriad economic, political, and social forces.

**Limitations**

Limitations to this study, its methods, and conclusion include the use of narrow survey and interview recruitment (e.g. only two universities in two cities), a subsequently unrepresentative sample pool (college students and Uruguayan professionals), and a relatively short survey. Future projects should broaden the scope and recruitment of the participant pools, geographically speaking, to limit the risk of intervening variables. In addition, educated Uruguayans were overrepresented in the interviews, as snowball sampling was
used via university faculty. Future research should better control for such factors as education, income, and political affiliation in interview recruitment in order to more precisely test the findings of this paper and expand the survey itself to investigate perception of individual social mobility as well as societal social mobility. Further, the tool of longitudinal comparison used—interviews with older generations of Uruguayans—is a limitation to this study. The lack of longitudinal data concerning Uruguayan perceptions of social mobility and consumerism precludes hard data comparison. The use of interviews with older Uruguayans as a means of intergenerational comparison (in the absence of trend data) without similar interviews in the US limits the comparability of both data sets. To explore change in the US, literature and data were utilized, while interviews in Uruguay served the same purpose—a notable limitation in any comparative study. Thus, discussion and comparison of US and Uruguayan trends over time is precarious, needing further and more robust research.

ACKNOWLEDGEMENTS

I appreciate the comments and support from Dr. Stephen Sills.

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Figure 2: The reinforcing relationship of increasing consumerism and collective perception of greater fluidity in social mobility
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Perceptions of Charitable Giving: Discovering and Understanding Societal Views to Maximize the Ability to Build Homes, Hopes, and Futures

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ABSTRACT
Watauga County Habitat for Humanity is always in need of additional volunteers and donations to most efficiently improve the community with their home building efforts. A survey was developed and distributed to friends and family of Appalachian State University’s Communication Research Methods class to gauge the public’s perception of charitable giving in general, as well as Habitat for Humanity specifically. The study uncovered descriptive attributes of Habitat for Humanity and themed statements related to charitable giving that our participants found favorable. It also revealed that charities with strong reputations had a more positive public perception among our participants, and the use of keywords relating to positive ethical values may be more impactful in marketing and advertising for charitable organizations. These words clustered in three groups echoing Aristotle’s persuasion modes of ethos, pathos, and logos. The results of the study were analyzed to make recommendations for marketing and fundraising strategies for Watauga County Habitat for Humanity, such as promoting values that align with societal ethics and morals when advertising to increase the public’s willingness to volunteer with or donate to the organization.

Habitat for Humanity International was founded in 1976 and has become the number one homebuilder in the world (Croce, 2016). Habitat for Humanity’s regional divisions have developed partnerships within their respective communities to help build homes for those in need so they may attain the dream of homeownership. Since its conception, this organization has helped 6.8 million families worldwide, with 25 of these families being housed by Watauga County Habitat for Humanity (Habitat for Humanity, 2016; Watauga County Habitat for Humanity, 2016).

The Watauga County Habitat for Humanity organization was seeking more volunteers and donations to continue and expand their home building efforts. Watauga County, located in western North Carolina on the border of Tennessee’s Cherokee National Forest, has been named a “difficult to live in” county by the United States Department of Housing and Urban Development for nearly a decade, due in part to the area’s lack of affordable housing. Nearly one-third of Watauga County residents lived below the poverty line as of 2013 (Appalachian District Health Department, 2016).

Watauga County Habitat for Humanity partnered with Appalachian State University (located in Boone, Watauga County’s county seat and largest town) to find a way to more
effectively engage with donors and volunteers. After completing background research about the organization, interviews were conducted by Appalachian State University’s Communication Research Methods class to obtain information necessary to create a unique survey instrument. Participants were asked about their perception of charitable giving, as well as to provide their opinions of Habitat for Humanity in ten single, descriptive words. The results were compiled and dissected to obtain themed statements that described charitable giving, and adjectives that described Habitat for Humanity, based on their comments. A survey was then designed and distributed and the results analyzed to provide recommendations for the organization’s communication with the public to increase donations of volunteer efforts and building supplies.

Sargeant (1999) studied individuals’ giving behaviors, as well as how charities communicate, to determine how these influences may affect individuals’ charitable donations. Sargeant’s research suggested that charities focusing their efforts on the targeted donors most likely to assist them would likely reduce the organization’s donor acquisition cost. He found that there were several motivational factors that could encourage people to donate to charities, including whether the donor believed they would receive any social or political benefit, whether the donor’s support would be visible to others, and whether the donor perceived an organization as financially efficient. One especially important factor that seemed to influence charitable giving was whether an individual has personal experience (either themselves or through a family member or close friend) with the problem addressed by the charity, especially in the case of charities devoted to researching specific medical conditions.

Sargeant proposed that the perception of a charity’s appeals by the public was a great influence on individuals’ decision-making processes (specifically, in making the decision to support that charity or not). He also found that a potential donor’s demographics (especially their age, gender, and level of income) were key determinants of whether, and how much, that individual would be likely to donate. In his report, Sargeant cited other researchers’ work that noted that females were more likely to engage in charitable giving if they had a thorough explanation of how their money would be used, and were more likely to give ‘from the heart than the head’. He also cited earlier research that found that individuals in lower socioeconomic classes identified more with recipients of charities and were hence more likely to donate to charities themselves, and that those wealthier gave in their own self-interests or due to feelings of social responsibility. Both of these groups (the wealthy and the working class) were found to give a higher proportion of their income than individuals considered middle-class. Also, prior studies suggested that individuals motivated by intrinsic rewards (such as increasing their feeling of self-worth or finding comfort in relieving another’s suffering) were more motivated to donate to charities than those seeking external rewards (for example, to conform to social norms or receive recognition).

Individuals’ demographics influence their perceptions of (and donations to) charity, and key words or themes can be used in a charitable organization’s marketing messaging to more effectively influence potential donors to give to their cause. Inspired by Sargeant’s findings and suggestions for future research on this topic, specific themes that could be used in charities’ marketing communications to increase the likelihood of convincing the public to donate to or volunteer with the organization were sought. The study was designed to uncover keywords and their underlying themes with the ultimate goal to make recommendations to Watauga County Habitat for Humanity, in an effort to improve the effectiveness of their marketing messages, and, in turn, the success of the organization.

Previous research on general perceptions of charitable giving provides insight on how individuals decide whether or not to support a charity through donations or volunteering.
Knowing what factors drive individuals to donate is beneficial, as it allows charities to target certain audiences through their messages (Vesterlund, 2006). Factors that determine how charitable giving is perceived and influenced can be separated into two categories: public incentives and private incentives.

Those who are influenced by public incentives choose to donate time or money due to its positive influence on the community and benefit to those who are in need of assistance. These individuals may take into account the goals of a charity when deciding where to allocate donations (Smith & Schwarz, 2012). These individuals perceive charitable giving as a way to encourage community growth and to help others. Charities that craft their messages effectively can target this type of audience. Because of their concern for those they help, these individuals may cease their charitable giving if a charity insinuates that those who are being helped are responsible for their unfortunate situation (Cole, 2014). Due to this mindset, organizations should avoid blaming those they are helping so as to not discourage donations (Lee, Winterich, & Ross, 2014).

Those who focus more on the way that donating affects them personally are motivated by private incentives (Vesterlund, 2006). These individuals perceive charitable giving as a way for themselves to gain something, such as a feeling of accomplishment or a tax incentive. People who find that their morals and values match those of a specific charity are more likely to associate with that charity and donate to that cause (Smith & Schwarz, 2012). An economics professor at Williams College, Jon Bakija, acknowledges this factor and suggests that tax subsidies on monetary donations promote giving and improve the level of charitable donations in the United States (Povich, 2013). Vice President of the National Council of Nonprofits David L. Thompson (2013) agrees with Bakija, adding that charitable giving benefits society as a whole and it is imperative to promote generosity by having the government provide tax benefits to those who donate to charity. This suggestion is one way that individuals who are influenced by private incentives can be targeted and encouraged to donate more.

Perceptions specific to Habitat for Humanity allow insight into how this organization is regarded by the public. Habitat for Humanity was listed in fourth place in the Cone Nonprofit Power Brand report, a public ranking of nonprofits, in 2009, as they were commended for their brand image and public perception (Cohen, 2011). One study found that Habitat for Humanity was very effective at building low-income homes efficiently and that this work was extraordinary considering the organization’s dependence on volunteer efforts and donations (Hays, 2003). The homes that are built were found to be beneficial to society as a whole, as they allow for homeowners to have a safe place to live and provide them the ability to focus their attention on their educations, careers, and well-being (Evans, et al., 2000). Even though many are aware of Habitat for Humanity’s positive influence on the communities they serve, many misconceptions about this organization and its purpose remain.

In general, Habitat for Humanity is seen as a domestic, faith-based organization that focuses on the needs of those in the United States (Cohen, 2011). In reality, Habitat for Humanity is part a very large network throughout the world that helps families in many countries. Although Habitat for Humanity is an organization founded upon Christian beliefs, it does not only assist or seek assistance from individuals of Christian faith. Most of their efforts are non-denominational, as Habitat for Humanity helps people of all religions in countries throughout the world, even though they are seen as an organization that does small, religious charity jobs within the U.S. Conversely, there are also many who are unaware of the fact that Habitat for Humanity is a Christian-based organization (Mueller & Hooker, 2015).

One complaint about Habitat for Humanity’s work is that they are not perceived to have provided for the larger community when building one home for a single
family. It is thought that those who receive the home are receiving a very generous donation, but it is not well known that each family is required to help build their home alongside the Habitat for Humanity volunteers. Home recipients are also responsible for paying for their home, though the price is reduced due to volunteer labor and the mortgage is interest-free. Habitat for Humanity’s ReStores, their retail locations that accept donations of home-building materials, are also commonly misidentified as The Salvation Army or Goodwill, which can impede the organization’s brand image (Cohen, 2011).

The professional website Indeed allows individuals to anonymously review their experiences with businesses they have worked for. Organizations are rated on a scale from 1 to 5 stars. Habitat for Humanity achieved a 4.4-star rating with over 500 reviews, an outstanding rating that portrays a positive public image (“Habitat for Humanity Employee Reviews”, Indeed, 2015). This rating system can encourage those who wish to volunteer with (or donate to) Habitat for Humanity, as they can see that this organization has been rated highly by current and former volunteers and employees. Many positive comments are listed on the page and this allows interested individuals to see that Habitat for Humanity has been considered by others a great organization to work for. Adversely, there are some negative comments left in these reviews, primarily regarding the actual work of building the home and the lack of pay.

In general, research on this topic led to the conclusion that there are public and private incentives the motivate volunteers and donors, and these qualities need to be considered when attempting to gain more individual participation. Many perceptions of Habitat for Humanity are misconceptions that should be addressed by the organization. Individuals interested in volunteering can access websites like Indeed that can encourage their contributions to organizations like Habitat for Humanity. Understanding the general perception of charitable giving and the misconceptions about Habitat for Humanity are vital to the design and success of this research, and subsequent studies that seek to determine how to improve these opinions and increase volunteer participation and donations.

**METHODOLOGY**

Initial qualitative interviews were conducted by the student researchers to obtain the participants’ individual perceptions of charitable giving, with which the survey instrument would be designed. Interview respondents were qualified as being familiar with charities and were selected through a convenience sample. A total of 28 interviews were collected. Interviewees were asked general questions related to their experiences with and perception of charitable giving. The respondents were also asked to provide at least ten descriptive words they felt best defined Habitat for Humanity.

These open-ended discussions were then analyzed by all student researchers, where statements related to charitable giving were narrowed down into eight themed statements based on their commonalities. The themed statements related to the perception of charitable giving were deduced based on how often these topics were raised by respondents in the students’ interviews. These statements were: “I believe in charities that are transparent about how they allocate donations”, “I support charities that make my community better”, “Charities that focus on the needs of specific individuals are most important to me”, “A charity must have a good reputation”, “I associate with charities that have a religious affiliation”, “A charitable organization that demonstrates a love for people is important”, “Volunteering by giving time is the most appropriate way to support a charity”, and “I am attracted to charities that feature a celebrity spokesperson”.

The adjective list from each survey respondent was collected in a master document. Based on frequency, adjectives that participants believed best described Habitat for Humanity were: Humanitarian, Generous, Compassionate, Wonderful, Community,

The eight themed statements relating to charitable giving and the descriptive words pertaining to the perception of Habitat for Humanity were then used to design an online survey. The eight themed statements were placed in a matrix format question, with Likert scale response options of strongly agree, agree, neutral, disagree, or strongly disagree. To measure the relevance of descriptive adjectives of Habitat for Humanity, participants were given the same Likert scale response options. Demographic questions, including the participants’ educational level, age, employment status, household income, annual amount of charitable donations, marital status, presence of children in the household, and ethnicity, were also included in the instrument.

The online survey instrument was distributed electronically through convenience, judgmental, and snowball sampling techniques. Participants received the survey instrument via a direct email or by clicking on a social media link posted by one of the students. The survey was then completed anonymously. A total of 804 discrete responses were collected. Seven surveys received were incomplete and, consequently, omitted from our analysis. The final total of usable survey responses was 797. Though demographic questions were included, no identifying information was collected from respondents. Participants were not compensated for completing the survey.

The Statistical Analysis Software Package (SPSS) was used to conduct analyses of the data collected by the survey. To begin analyses on the twenty descriptive adjectives pertaining to Habitat for Humanity (Humanitarian, Generous, Compassionate, Wonderful, Community, Admirable, Hopeful, Life-Changing, Workers, Volunteer, Building, Caring, Kindness, Charitable, Supportive, Good, Helpful, Needed, Home, and Giving), an Exploratory Factor Analysis (EFA) was performed. These words were separated into three word clusters and analyzed for underlying themes.

Next, the eight themed statements were tested for reliability by calculating Cronbach’s alpha. This testing determines the level of internal consistency among the scale items, to assure all items measure the same construct.

Then relationships among the pairs of items and the themed statements were conducted with Pearson’s correlations. Next, an Exploratory Factor Analysis was conducted on the eight themed statements related to perception of charitable giving. The eigenvalue determines how strongly a group of responses is related, and researchers generally hope to find an eigenvalue equal to or higher than 1 (Ledesma & Valero-Mora, 2007). This analysis highlights more manageable clusters of data that are correlated with each other, as well as underlying connections within the data that might not otherwise be visible to researchers studying the full data set.

Analysis of Variance (ANOVA) testing was performed to determine if there were significant differences among the categories within the descriptive variables, related to perception of charitable giving. Regression analysis was performed to determine if any of the word clusters representing perception of Habitat for Humanity were unique significant predictors of perceptions of charitable giving.

RESULTS AND DISCUSSION

The demographic information collected from the 797 survey respondents was analyzed. The largest age group among the respondents was 18 to 31 years old (44%). A majority (61%) were married or living with their significant other, and 64% did not have dependent children or other minors living in their household. Most of the respondents, 84%, categorized themselves as Non-Hispanic White or Euro-American, and 7% identified as Black, Afro-Caribbean, or African American. A significant number of responses
from South Asian, Indian American, Middle Eastern, Arab American, Native American, or Alaskan Native individuals were not received.

Over half of the participants indicated that they had earned a college degree (57%), and others had completed some college (27%). Most identified as an employee of a business (44%), while some held management positions (17%), or were the owner of a business (12%). Over half of the respondents said that they earned less than $60,000 annually (55%), but a significant percentage of participants (15%) placed their annual income level at over $100,000. Nearly two-thirds (64%) of participants said that they donated less than $1,000 to charities annually, while one-quarter claimed that they gave between $1,000 and $5,000.

Exploratory factor analysis was conducted to dimensionalize the descriptive words that represented perceptions of Habitat for Humanity. The first analysis collected the items into one factor. Researchers commonly must decide how many factors to separate data into when performing an EFA, and this decision is important as analytical results can vary widely if the number is either too large or small (Ledesma & Valero-Mora, 2007). The EFA on the descriptive words was conducted by separating the data into three word clusters.

The most powerful word cluster collected the words Supportive, Generous, Compassionate, Wonderful, Admirable, Hopeful, Caring, Kindness, Charitable, and Giving, and had an eigenvalue of 7.17. The second most powerful word cluster was created by the words Life-Changing, Workers, Volunteer, and Building, which invoke the actual process of home building and appeal to logic. The eigenvalue of this cluster was 4.44. The remaining words (Home and Humanitarian) were sorted into the third cluster. These words suggest an appeal to ethics, an obligation to do what is right for the community and help others that are in need. This cluster’s eigenvalue was 3.87. Three words were confounded (Helpful, Good, and Needed), while one word, Community, did not load into any of the three factors.

After considering the underlying themes of the related words within clusters one, two, and three, the groups were named after the modes of persuasion first described by Aristotle, respectively: “Pathos”, appealing to the audience’s emotions; “Logos”, relating to logical or factual appeals; and “Ethos”, based on ethics or a speaker’s credibility.

The test to determine internal reliability indicated that the eight themed statements that measure perceptions of charitable giving achieved a 0.49 Cronbach’s alpha. Researchers often look for a Cronbach’s alpha of 0.7 or higher to confirm that the data are, indeed, consistent (George & Mallery, 2003). A Cronbach’s alpha below this 0.7 threshold may indicate low inter-relatedness within data, or it may be the result of a survey instrument with too few questions (Tavakol & Dennick, 2011).

Because reliability was not achieved among scale items, correlation testing was conducted. Correlation testing found the effect size ($r$) of each pair to determine the strength of the correlations between the themed statements. Effect sizes are categorized as follows: Small, positive correlation (0.10-0.29); medium, positive correlation (0.30-0.49); large, positive correlation (0.50-1.0). The following pairs had the strongest correlations: “A charity must have a good reputation” and “A charitable organization that demonstrates a love for people is important”, $r = 0.35$; “A charitable organization that demonstrates a love for people is important” and “I support charities that make my community better”, $r = 0.31$; “I believe in charities that are transparent about how they allocate donations” and “I support charities that make my community better”, $r = 0.27$.

There were negatively correlated statements, as well. In fact, all negative statements were associated with the phrase “I am attracted to charities that feature a celebrity spokesperson”. The statements that were negatively correlated with this phrase were: “I support charities that make my community
Table 1. Rotated Components Matrix of the Factor Analysis of Adjectives Related to Perception of Habitat for Humanity

<table>
<thead>
<tr>
<th>Supportive</th>
<th>Generous</th>
<th>Compassionate</th>
<th>Wonderful</th>
<th>Admirable</th>
<th>Hopeful</th>
<th>Caring</th>
<th>Kindness</th>
<th>Charitable</th>
<th>Giving</th>
<th>Life-Changing</th>
<th>Workers</th>
<th>Volunteer</th>
<th>Building</th>
<th>Home</th>
<th>Humanitarian</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.63</td>
<td>0.71</td>
<td>0.75</td>
<td>0.78</td>
<td>0.65</td>
<td>0.68</td>
<td>0.74</td>
<td>0.77</td>
<td>0.70</td>
<td>0.72</td>
<td>0.50</td>
<td>0.74</td>
<td>0.79</td>
<td>0.72</td>
<td>0.74</td>
<td>0.64</td>
</tr>
</tbody>
</table>

Note: Three adjectives - Good, Helpful, and Needed - were confounded, and one adjective - Community - did not load into any factor using the Principal Components extraction method.

better” (r = -0.54), “I believe in charities that are transparent about how they allocate donations” (r = -0.06), “A charitable organization that demonstrates a love for people is important” (r = 0.08), and “A charity must have a good reputation” (r = -0.04). All effect sizes of the negative correlations were weak.

EFA was conducted on the eight themed statements. The rotated solution provided two factors, with one predominant factor, which had an eigenvalue of 1.79. The factor collected “A charity must have a good reputation”, “A charitable organization that demonstrates a love for people is important”, “I support charities that make my community better”, and “I believe in charities that are transparent about how they allocate donations”.

The four themed statements were collapsed in a dependent variable, which was used for Analysis of Variance (ANOVA) and regression testing. ANOVA testing was performed to compare means among categories within each demographic variable and see whether there were statistically significant differences among them. The only demographic that had significance was “marital status”, although it was weak with an effect size of 0.018.

The next test conducted was a regression analysis to determine if there were any word clusters that were unique significant predictors of perceptions of charitable giving. One cluster was a unique significant predictor of charitable giving. It was the “Ethos” cluster which collected the terms Home and Humanitarian.

The basis for this research, that specific keywords could be used in charities’ marketing communications to positively affect the public’s level of volunteering and donations, was the foundation for the suggestions that
Table 2. Correlation Coefficient Values Between Eight Themed Statements Related to Perceptions of Charitable Giving

<table>
<thead>
<tr>
<th>Statement</th>
<th>Religious</th>
<th>Celebrity</th>
<th>Volunteering</th>
<th>Community</th>
<th>Transparent</th>
<th>Individuals</th>
<th>Love for People</th>
<th>Reputation</th>
</tr>
</thead>
<tbody>
<tr>
<td>A charity must have a good reputation. (Reputation)</td>
<td>0.112**</td>
<td>-0.042</td>
<td>0.032</td>
<td>0.252**</td>
<td>0.185**</td>
<td>0.080*</td>
<td>0.358**</td>
<td></td>
</tr>
<tr>
<td>A charitable organization that demonstrates a love for people is important. (Love for People)</td>
<td>0.185**</td>
<td>-0.081*</td>
<td>0.148**</td>
<td>0.318**</td>
<td>0.176**</td>
<td>0.262**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Charities that focus on the needs of specific individuals are most important to me. (Individuals)</td>
<td>0.120**</td>
<td>0.064</td>
<td>0.156**</td>
<td>0.140**</td>
<td>0.078*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I believe in charities that are transparent about how they allocate donations. (Transparent)</td>
<td>-0.008</td>
<td>-0.064</td>
<td>0.030</td>
<td>0.272**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I support charities that make my community better. (Community)</td>
<td>0.169**</td>
<td>-0.054</td>
<td>0.173**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volunteering by giving time is the most appropriate way to support a charity. (Volunteering)</td>
<td>0.109**</td>
<td>0.056</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I am attracted to charities that feature a celebrity spokesperson. (Celebrity)</td>
<td>0.420</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I associate with charities that have a religious affiliation. (Religious)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*p < .05; **p < .01, 2-tailed test.

Table 3. Rotated Components Matrix of the Factor Analysis of Statements Related to Perception of Charitable Giving

<table>
<thead>
<tr>
<th>Statement</th>
<th>Component 1</th>
<th>Component 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>A charity must have a good reputation.</td>
<td>0.64</td>
<td></td>
</tr>
<tr>
<td>A charitable organization that demonstrates a love for people is important.</td>
<td>0.63</td>
<td></td>
</tr>
<tr>
<td>I support charities that make my community better.</td>
<td>0.63</td>
<td></td>
</tr>
<tr>
<td>I believe in charities that are transparent about how they allocate donations.</td>
<td>0.61</td>
<td></td>
</tr>
<tr>
<td>Volunteering by giving time is the most appropriate way to support a charity.</td>
<td>0.60</td>
<td></td>
</tr>
<tr>
<td>Charities that focus on the needs of specific individuals are most important to me.</td>
<td>0.58</td>
<td></td>
</tr>
<tr>
<td>I associate with charities that have a religious affiliation.</td>
<td>0.52</td>
<td></td>
</tr>
<tr>
<td>I am attracted to charities that feature a celebrity spokesperson.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
were made to Watauga County Habitat for Humanity regarding how their advertising and other messaging could be improved to attract more volunteers and donors. We found that individuals’ demographics did influence their perceptions of charitable giving, though to a small extent, and that key themes can be used in an organization’s messaging to more effectively influence potential donors.

The correlations of the themed statements suggested that those who are interested in donating to charities prefer organizations that have a good reputation, demonstrate a love for people, work to make the community better, and are transparent about how they allocate received donations. This information is useful when determining how potential donors view charities and how they decide which ones they will associate with. Those who are looking for charities with a religious affiliation may not be as concerned about the charity’s donation allocation transparency, and vice versa. Also, the celebrity spokesperson themed statement negatively correlated with statements about making the community better, being transparent about allocating donations, demonstrating a love for people, and having a good reputation (the four statements that have been found to be important to a positive charity affiliation), further suggesting that a celebrity spokesperson is not necessary for positive perceptions of charitable giving.

ANOVA testing showed that marital status was significantly related to the ethical statements, and that the strongest relation was among those participants who indicated that they were separated. This suggests that Habitat for Humanity should consider that the population has a wide variety of opinions when it comes to charitable giving, and that marital status may be important to consider.

EFA testing on the descriptive adjectives showed that the significance of the terms in the first cluster, Pathos, suggests that these emotionally-charged words are most impactful to Habitat for Humanity’s target audience. The words in the Pathos cluster were: Supportive, Generous, Compassionate, Wonderful, Admirable, Hopeful, Caring, Kindness, Charitable, and Giving, and these words may positively influence those who may consider donating to and/or volunteering with Habitat for Humanity if they are integrated into advertising and marketing messages. These adjectives successfully appeal to emotions and help consumers connect with Habitat for Humanity’s message.

The Logos and Ethos clusters also provide some insight, although not as strongly as the first category. Words in the Logos cluster (Life-Changing, Workers, Volunteer, and Building) may appeal to the public’s sense of logic. Words in the Ethos category (Home and Humanitarian) appeal to a sense of ethics, such as an obligation to do what is right for the community and help people that are in need.

The final test conducted was regression analysis to determine if the descriptive word clusters Pathos, Ethos, and Logos were significant predictors of perceptions of charitable giving. The four themed statements, collapsed into one variable, were once again used as the dependent variable. One cluster of words proved to be a significant predictor, which included the words Home and Humanitarian. Regression testing on the descriptive adjectives showed these words to be strong predictors of behaviors toward the four ethically-themed statements. These words were also found to have an underlying ethical appeal, correlating with “I support charities that make my community better”, “I believe in charities that are transparent about how they allocate donations”, “A charitable organization that demonstrates a love for people is important”, and “A charity must have a good reputation”. The words (or visual depictions that invoke the ideas of) Home and Humanitarian should be implemented in Habitat for Humanity’s messages to suggest that Habitat for Humanity is a charity that has a good reputation, is transparent about how they allocate donations, demonstrates a love for people, and makes the community better.

Regression testing indicated that the words Home and Humanitarian lead people to believe the message that Habitat for Humanity
is a charity that fulfills their expectations. This information could be useful to Habitat for Humanity, as well as other charitable or nonprofit organizations, when crafting fundraising or volunteer-seeking marketing campaigns. By understanding how potential donors or volunteers view charities, and how they ultimately decide which ones they will support, these organizations can better determine how to most effectively present their appeals.

Overall, our respondents looked for underlying ethical values of charities, so promoting the ethical aspects of Habitat for Humanity’s charitable giving would be beneficial. Association with a celebrity spokesperson is discouraged, as this factor was proven to be negatively correlated with the ethically-themed statements that were proven to be beneficial to the organization. Words with emotional appeal should be implemented to persuade those who are compelled by emotional values to donate and volunteer. Habitat for Humanity should highlight its long history and good reputation, and demonstrate that the organization is based on a love for people. Also, their marketing campaigns would benefit by suggesting that their work makes the communities they assist better, and that they act with transparency about the way donations to the organization, and to the people the organization helps, are allocated.

LIMITATIONS

As with any research, there are factors that impede the research process and limit results. Through the interviewing process, sampling method, and electronic surveying, responses were obtained from across the state of North Carolina, as well as across the country. Also, convenience sampling occurred by sending the survey electronically to friends, family, and social media contacts of the class, as well as to those who had the survey redistributed to them, so a preferred stratified random sample was not obtained. Lastly, demographic information related to gender was omitted from the survey instrument, which prevented analysis of this demographic. Therefore, suggestions cannot be made concerning perceptions of charitable giving and Habitat for Humanity that may differ by gender.

Our pool of survey respondents was composed primarily of individuals identifying themselves as Non-Hispanic White or Euro-American (84%). Watauga County, North Carolina reports that slightly over 95% of their population fits into this category, according to the United States Census Bureau (2015). Seven percent of survey participants identified themselves as Black, Afro-Caribbean, or African-American (the second largest demographic group in our study), as compared to 2% of Watauga County residents. This difference in reported demographics suggests that our survey was completed by a population more ethnically diverse than the county this study was completed to benefit. Education levels and marital status rates may also differ from our survey population to a statistically significant degree. The survey respondents were not specifically from Watauga County and the respondent demographics did not parallel the population of Watauga County specifically. As such, our findings may not accurately reflect the perceptions of the residents in this particular community.

SUGGESTED FUTURE RESEARCH

There is abundant room for future research on society’s perceptions of charitable giving, and specifically on keywords or themes an organization can use to encourage the public’s willingness to donate their time or money to a cause. Further exploration into how perceptions of charitable giving vary according to respondents’ religious affiliations, income levels, and gender identity would almost certainly yield additional valuable information. Other appeals not captured by this study, particularly as they apply to more diverse demographics (specifically, minority groups), could have a greater impact on an organization’s ability to learn how to best reach potential donors than the appeals studied here. Expanding upon this research
would benefit not only Habitat for Humanity, but other charitable or humanitarian organizations, and the communities that they serve. Utilization of a stratified random sample of a larger size, as well as additional variables, is advised for those conducting future research in this area.

ACKNOWLEDGEMENTS

We would like to thank the following people for their contributions to the study and preparation of this report: Mr. Alex Hooker, for his time in the interview process and helping the class understand Watauga County Habitat for Humanity’s unique challenges and concerns, as well as future vision; Appalachian State University’s Fall 2015 Communication Research Methods class, for their hard work and participation in all steps of this research, including survey design, response procurement, and data analysis; James Simpson for his contributions to the original project that was presented to Watauga County Habitat for Humanity; and Dr. Thomas S. Mueller, for his valuable guidance and encouragement throughout this project.

REFERENCES


Jenna Friday and Sarah Meyer


The Association Between Women’s Empowerment and Child Nutrition in Bangladesh

Anika Hannan
University of North Carolina Chapel Hill
Faculty Mentor: Kavita Singh Ongechi
University of North Carolina Chapel Hill

ABSTRACT
As the United Nations transitions from the Millennium Development Goals to the Sustainable Development Goals, ending hunger and improving nutrition remains a top priority for international development (Coonrod, 2014). Despite this priority, child malnutrition in Bangladesh remains one of the highest in the world (Bhagowalia, Menon, Quisumbing, & Soundararajan, 2012). Evidence suggests that the low social status of women in South Asia contributes to this rate (Shroff, Griffiths, Suchindran, Nagalla, Vazir, & Bentley, 2011). This research paper examines the association between women’s empowerment and child nutrition in Bangladesh, using data from the 2011 Bangladesh Demographic and Health Survey (DHS). Women’s empowerment was captured through constructs of mobility, decision-making power, views on violence, and membership in microcredit or social organizations. Child malnutrition was measured using the following outcomes: stunting (low height for age), wasting (low weight for height), and underweight (low weight for age). Based on bivariate results using logistic regression, views on violence and organization membership were statistically significant with malnutrition outcomes. However, when the controls of wealth status, mother’s education, and father’s education were added to the model, the relationship was no longer significant. These results suggest that wealth and education have a stronger effect on childhood malnutrition than women’s empowerment, and independently affect both child malnutrition and empowerment status. In order to create and improve existing policies focused on achieving the second Sustainable Development Goal of ending hunger and improving nutrition, further research is necessary to better understand the relationship between wealth, education, empowerment, and child malnutrition.

In the year 2000, the United Nations developed the Millennium Development Goals (MDGs). The eight MDGs were global objectives that addressed extreme poverty and health and expired in 2015; the first MDG was to eradicate extreme poverty and hunger (United Nations Millennium Development Goals, 2015). A goal’s expiration date indicates its desired success date, after which the United Nations reevaluates the goals and sets new ones. The latest of these dates expire in 2030. While poverty was cut in half by its expiration date in 2015, hunger remains a problem with 1 in 9 people in the world remaining hungry (United Nations Millennium Development Goals, 2015). Hunger is defined by the United Nations as “not having enough to eat to meet daily energy requirements” (Hunger Glossary, 2015). Set to expire in 2030, the UN has adopted the Sustainable Development Goals, which focus on international development in a sustainable context (Sustainable Development Knowledge Platform, 2015). Understanding
the association of different structural, societal factors on nutrition is necessary in order to meet the Sustainable Development Goals set for the year 2030.

Long-term hunger can lead to malnutrition, a condition when an individual’s diet does not provide adequate nutrients for growth and development (Hunger Glossary, 2015). Children under the age of 5 are the most susceptible population to malnutrition. In low and middle-income countries, 1 in 6 children are malnourished (Hunger Statistics, 2015), becoming more susceptible to preventable diseases such as pneumonia, malaria, measles, and diarrheal diseases. The effects of these diseases are magnified when a child is undernourished, increasing the number of deaths that occur from these preventable diseases (Hunger Statistics, 2015). It was estimated that malnutrition was the cause of about 45% of all children deaths in 2011 (Black, et al., 2013). In addition, malnourished children may have damaging long-term health effects, such as hypertension and poor mental development (Martins et al., 2011). Malnourishment is a vicious cycle. Malnourished children have lower educational achievements and become low wage earning adults. Lower wages reduce purchasing power for nutritious foods and these adults in turn have malnourished children, continuing the cycle (Martins et al., 2011).

On a global scale, South Asia has the highest rate of malnutrition. Despite decreasing rates of malnutrition in the past few decades, the rates remain very high; about 46% of the children in South Asia are malnourished (The South Asia Food and Nutrition Security Problem, 2015). Of the countries in South Asia, Bangladesh is the focus of this study due to its growing population and highest worldwide rate of chronic malnutrition; about 41% of the children in Bangladesh were chronically malnourished in 2011 (Malnutrition In Bangladesh: New Report Published, 2015). Compared to Bangladesh’s staggering economic growth between 2000 to 2010, malnutrition rates of children under the age of 5 are high and have not improved (The South Asia Food and Nutrition Security Problem, 2015).

South Asia’s high percentage of malnourished children is believed to be impacted by the low status of women (Smith et al., 2003; Sethuraman et al., 2006; Shroff et al., 2009). Previous research has studied this relationship in Bangladesh’s neighboring countries, however, not much has been done in Bangladesh. This study seeks to examine the role of women on the high malnutrition rates in Bangladesh and add to the body of literature surrounding this relationship.

LITERATURE REVIEW

Empowerment is an abstract construct that is challenging to define with various meanings depending on the context. Overall, empowerment is an increase in political, social, or economic strength of an individual and developing confidence in one’s own capabilities (Definition: Women Empowerment, 2015).

Based on prior literature, many studies have found an association between women’s empowerment and child nutrition. While empowerment is measured differently in each study, improving a woman’s autonomy or capacity is considered to have a positive impact on child nutrition.

One extensive cross sectional study of 36 countries found that a woman’s status does influence child’s nutritional status in three regions of the world: South Asia, Sub-Saharan Africa, and Latin America and the Caribbean (Smith et al., 2003). The study found that relative decision-making power has a strong positive association with child nutritional status in South Asia as a whole. In addition, societal gender equality had a positive impact on child nutritional status in South Asia and a woman’s relative decision-making power on child nutritional status is stronger among poorer households in all three regions.

Among studies of malnutrition within South Asia, a study conducted in 2006 in tribal and rural communities in Karnataka, India classified empowerment as a woman’s autonomy of choices, control, and power and
classified child malnutrition as undernutrition (Sethuraman, Lansdown, & Sullivan, 2006). The authors observed that a woman’s empowerment is significantly associated with a child’s underweight status and maternal nutritional status, and psychological violence indirectly disempowers mothers, both of which exacerbate malnutrition (Sethuraman, Lansdown, & Sullivan, 2006).

Another study examined the relationship of women’s autonomy on child stunting in Andhra Pradesh, India and found certain autonomy characteristics are significantly associated with child stunting (Shroff, Griffiths, Suchindran, Nagalla, Vazir, & Bentley, 2011). The study measured autonomy as decision-making power, permission to travel alone, attitude toward domestic violence, and financial autonomy (Shroff, Griffiths, Suchindran, Nagalla, Vazir, & Bentley, 2011). Permission to go to the market and financial autonomy were significantly associated with child stunting, along with the child’s age, maternal education, standard of living, and geographic location of residence (Shroff, Griffiths, Suchindran, Nagalla, Vazir, & Bentley, 2011).

One study conducted in Bangladesh in 2012 examined the relationship of women’s empowerment and child nutrition. The study observed various dimensions of women’s empowerment including mobility, decision-making power, and attitudes on domestic violence on the effects of stunting and diet diversity in children under age 5 (Bhagowalia, Menon, Quisumbing, & Soundararajan, 2012). Attitudes on domestic violence, maternal education, maternal height, and age at first marriage were significantly correlated with child stunting (Bhagowalia, Menon, Quisumbing, & Soundararajan, 2012). In addition, maternal height and education were strong determinants of diet diversity. While this study is most similar to this study, it did not consider the other measures of child malnutrition and focused only on the long-term indicator of malnutrition: stunting (Bhagowalia, Menon, Quisumbing, & Soundararajan, 2012).

This study not only analyzes the effects of stunting on long-term malnutrition, but also wasting and underweight. The association between all 3 types of malnutrition and women’s empowerment has not been studied in Bangladesh. Analyzing all three outcomes simultaneously allows the comparison of the relationship between women’s empowerment and malnutrition as a whole.

Furthermore, the use of organization membership as an empowerment measurement has not been studied on the effects of child malnutrition. The Demographic and Health Survey (DHS) questionnaire asks about community organizations that range from microcredit organizations to mother care organizations. Community organizations as a whole allow women to exchange information and learn about available resources, such as nearby health clinics (Srivastava & Austin, 2012). Women in organizations form social bonds and relationships that increase child care knowledge, morale, and overall confidence that can translate into feelings of empowerment (Srivastava & Austin, 2012). In addition, many of the microcredit organizations focus explicitly on empowering women. For example, Grameen Bank teaches women about moneymaking and saving strategies, effective agricultural practices, and health and hygiene tips for herself and her child (Srivastava & Austin, 2012).

This study focuses on four dimensions of empowerment included in DHS: mobility, decision making, views on violence, and organization membership. The criteria for each empowerment dimension are described in the following paragraphs.

Mobility is classified in terms of a woman’s ability to visit a health clinic on her own, without being accompanied. Mobility to visit a health center unaccompanied allows a woman to expand her knowledge about her own health and her child’s health (Bhagowalia, Menon, Quisumbing, & Soundararajan, 2012). A woman who is of high mobility is not dependent on her spouse’s permission and can leave the house unescorted, allowing her to make independent decisions in regards to her and her children’s
health (Bhagowalia, Menon, Quisumbing, & Soundararajan, 2012). Women who do not have high mobility may not be exposed to new knowledge about health and childcare (Smith et al., 2003).

Decision-making is classified as a woman’s role in making household decisions independently or with her husband. A woman’s decision-making elevates her role and views within the household. Her participation in decisions increases her autonomy to decide which foods are prepared for the child and the type of care the child is receiving (Bhagowalia, Menon, Quisumbing, & Soundararajan, 2012).

A woman’s view of domestic violence has been previously shown to impact child nutrition. A study on different dimensions of women’s empowerment on stunting and diet diversity found a significant association between views on violence and child nutritional outcome of stunting (Bhagowalia, Menon, Quisumbing, & Soundararajan, 2012). It concluded the low status of woman and justification of beating shifts the power toward the male and is related to the long-term nutritional outcome of the child. In addition, another study found that mothers who experience physical and psychological abuse have higher rates of malnutrition among themselves and their children (Sethuraman, Lansdown, & Sullivan, 2006).

The microcredit or social organizations included in the DHS questionnaire incorporate a component of women’s empowerment in their mission or goal. Membership to a community organization allows women to exchange knowledge and tips for caring for themselves and their children, about local health services, and knowledge on budgeting and spending money (Women’s Status and Empowerment, 2015).

**DATA AND METHODS**

The 2011 Bangladesh Demographic and Health Survey (DHS) dataset is used in this study. The DHS is a nationally-representative household survey that provides data for a wide range of monitoring and impact evaluation indicators in the areas of population, health, and nutrition (DHS Overview, 2015). The DHS have large sample sizes and are typically conducted every 4 to 5 years in each country to allow comparisons over time (DHS Overview, 2015). The survey collects data from over 90 countries worldwide, which allows additional analyses among countries (DHS Overview, 2015). Wave 7 uses pre-existing national census frames and pre-selects the houses to interview.

From the total 17,842 respondents in the 2011 Bangladesh DHS, the analytic sample was restricted to mothers between the ages of 15 to 49 whose youngest child was under the age of 5 years (between 0 to 59 months). The analysis was conducted on 6,550 mother-child pairs.

**Women’s Empowerment Variables**

As mentioned, mobility, decision-making, views on violence, and organization membership are the four dimensions of empowerment. The survey questions pertaining to each dimension are described in the following paragraphs.

Mobility was defined as a woman’s response to the questions “Do you visit a health center alone?” A woman was classified as empowered if she answered yes and “not empowered” if she answered no or that she required accompaniment by her child, husband, or another individual.

Decision-making level was determined by a woman’s responses to 4 different questions about who made the decision about the child’s health, the respondent’s health, large household purchases, and visits to family and friends. A woman was classified as empowered if she responded that she either made the decisions alone or with her spouses. A woman was classified as not empowered if she did not participate in the decision making process at all.

A woman’s view on violence was determined by her response to 5 scenarios regarding when “wife beating” is justified. The scenarios included going out without telling
Control Variables

Several controls were studied that are likely to be associated with the outcome: child’s age, child’s sex, mother’s age, number of children the mother has, delivery location of the child, and geographic location of the household. In addition, controls that could be associated with both empowerment and the outcome were included such as parental education and household wealth.

METHODS

STATA 13 was used to conduct the analysis. A bivariate logistic regression determined the relationship between each of the nutritional status variables (stunting, wasting, underweight) with each of the empowerment variables (mobility, decision making, views on violence, organization membership). A different model was used to observe the relationship of each empowerment variable with the three nutritional outcomes making a total of 12 models. Significance was measured at the 0.05 α-level.

RESULTS

Table 1 presents a description of independent variables of empowerment and dependent variables of nutritional outcome. In

<table>
<thead>
<tr>
<th>Measure</th>
<th>Mean (proportion) weighted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Independent Variables</td>
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</tr>
<tr>
<td>Mobility (High)</td>
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</tr>
<tr>
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<tr>
<td>Organization Member (Yes)</td>
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<tr>
<td>Dependent Variables</td>
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</tr>
<tr>
<td>Wasted</td>
<td>0.159</td>
</tr>
<tr>
<td>Underweight</td>
<td>0.3474</td>
</tr>
</tbody>
</table>

Table 1. Descriptive: Independent and Dependent Variables

The study used three outcome measures to quantify child nutritional status. The first, stunting, was defined as low height for age and is a sign of chronic malnutrition. The second, wasting, was defined as low weight for height and is a sign of acute malnutrition. The third, underweight, was defined as low weight for age and is a combination of chronic and acute malnutrition. A child was considered as stunted, wasted, or underweight if the measurement fell 2 standard deviations below the mean set by the World Health Organization (Global Database on Child Growth and Malnutrition, 2015).

Nutritional Status Variables

The study used three outcome measures to quantify child nutritional status. The first, stunting, was defined as low height for age and is a sign of chronic malnutrition. The second, wasting, was defined as low weight for height and is a sign of acute malnutrition. The third, underweight, was defined as low weight for age and is a combination of chronic and acute malnutrition. A child was considered as stunted, wasted, or underweight if the measurement fell 2 standard deviations below the mean set by the World Health Organization (Global Database on Child Growth and Malnutrition, 2015).
terms of empowerment, 41% of the women were highly mobile, 41% had high household decision-making, 67% did not justify violence for any reason, and 35% were part of a microcredit or social organization. In terms of the child’s nutritional outcome, 40% were stunted, 16% were wasted, and 35% were underweight.

Table 2 presents the weighted means of the demographic variables. 52% of the children in the sample were male and the average age was 2 years. 26% of the children were born in a hospital or clinic setting. 44% of the women/mothers had finished secondary education (or 10th grade). The average mother of the sample was 25 years old and had 2 children. 77% of the mother-child pairs lived in rural areas. 30% of the husbands had finished secondary education.

Table 3 presents the bivariate analysis of empowerment variables and nutritional outcomes without the controls. The odds ratios for mobility and decision-making were close to 1, suggesting that these variables do not have an association with nutritional status. Women who were members of an organization had higher odds of having a child that was stunted, wasted, or underweight. Women who condemned violence had lower odds of having a child that was stunted, wasted or underweight.

Table 4 presents the multivariate analysis of empowerment variables and nutritional outcomes including the controls for parental education, wealth status, maternal characteristics and child characteristics. Like the results from the bivariate model, the odds ratios for mobility and decision-making remained close to 1, suggesting that these variables do not have an association with nutritional status. Similarly, women who condemned violence had lower odds of having a child who was stunted, wasted, or underweight. The odds ratio for women who were members of an organization changed direction from the bivariate model to the adjusted model to reflect odds ratios that suggest a woman who was in an organization had lower odds of having a child who was stunted, wasted, or underweight.

**DISCUSSION**

The results from this study build upon the findings of previous studies conducted on women’s empowerment and child nutrition. The variable of views on violence had an association with child nutrition that was consistent with the hypothesis while the variables mobility and organization membership had mixed results. The variable decision-making had little association with child nutrition, a finding similar to that of Bhagowalia and colleagues’ study (Bhagowalia, Menon, Quisumbing, & Soundararajan, 2012). The current study expanded on that by Bhagowalia and colleagues by incorporating the variables of wasting, underweight, and maternal organization membership and using an updated dataset. Despite these differences, both studies had similar findings and conclusions about the importance of maternal education on child nutrition.

For the mobility variable, the outcome was inconsistent with the initial hypothesis. From the results, a woman who was more mobile and could leave the house alone and without accompaniment, and therefore empowered, had higher odds of having a malnourished child than a woman who could not leave the house alone and needed accompaniment. This outcome can be explained by the way the variable mobility was coded. The survey asked the question “Do you go to the health clinic?” and had respondents that answered “Yes, alone” or “Yes, with husband” or named another person who served as an accompaniment. Since this question was the only one that asked about mobility outside of the home, it was used for constructing the mobility variable in this analysis. A woman who is aware of the existence and location of a health clinic and visits a clinic may have health-related needs for herself or her child. While the question does not ask how often a woman goes to a health clinic, the nature of the question suggests that it is a habitual action and occurs regularly. This may

Anika Hannan
<table>
<thead>
<tr>
<th>Measure</th>
<th>Mean (proportion weighted)</th>
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<tbody>
<tr>
<td><strong>Child</strong></td>
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<td>Age (Years)</td>
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<td><strong>Mother</strong></td>
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<td>0.1807</td>
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<td>4+</td>
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<td>Poorer</td>
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<tr>
<td>Middle</td>
<td>0.1982</td>
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<tr>
<td>Richer</td>
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<td>Richest</td>
<td>0.1941</td>
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<td><strong>Husband</strong></td>
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<tr>
<td>Higher</td>
<td>0.1322</td>
</tr>
</tbody>
</table>

*Table 2. Weighted Mean of Demographic Variables*
Table 3. Odds-Ratios (OR) and Confidence Intervals (CI) for Child Nutrition Outcomes based on Empowerment Variables

<table>
<thead>
<tr>
<th>Child Nutrition Outcome</th>
<th>Mobility</th>
<th>Decision Making</th>
<th>Views on Violence</th>
<th>Organization Membership</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stunted</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OR</td>
<td>1.051</td>
<td>0.978</td>
<td>0.858**</td>
<td>1.256***</td>
</tr>
<tr>
<td>CI</td>
<td>0.933, 1.185</td>
<td>0.870, 1.099</td>
<td>0.769, 0.958</td>
<td>1.123, 1.405</td>
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<tr>
<td><strong>Wasted</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OR</td>
<td>1.041</td>
<td>0.917</td>
<td>0.850*</td>
<td>1.018</td>
</tr>
<tr>
<td>CI</td>
<td>0.877, 1.235</td>
<td>0.786, 1.070</td>
<td>0.726, 0.996</td>
<td>0.867, 1.194</td>
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<tr>
<td><strong>Underweight</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OR</td>
<td>1.039</td>
<td>0.997</td>
<td>0.825**</td>
<td>1.198**</td>
</tr>
<tr>
<td>CI</td>
<td>0.924, 1.169</td>
<td>0.890, 1.117</td>
<td>0.733, 0.928</td>
<td>1.057, 1.359</td>
</tr>
</tbody>
</table>

Notes: N = 6550  Exponentiated coefficients  
*p < 0.05, ** p < 0.01, *** p < 0.001

Table 4. Adjusted Odds-Ratios (OR) and Confidence Intervals (CI) for Child Nutrition Outcomes based on Empowerment Variables

<table>
<thead>
<tr>
<th>Child Nutrition Outcome</th>
<th>Mobility</th>
<th>Decision Making</th>
<th>Views on Violence</th>
<th>Organization Membership</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stunted</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OR</td>
<td>1.053</td>
<td>0.978</td>
<td>0.974</td>
<td>.985</td>
</tr>
<tr>
<td>CI</td>
<td>0.924, 1.199</td>
<td>0.877, 1.116</td>
<td>0.870, 1.091</td>
<td>0.866, 1.121</td>
</tr>
<tr>
<td><strong>Wasted</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OR</td>
<td>1.067</td>
<td>0.953</td>
<td>0.916</td>
<td>.905</td>
</tr>
<tr>
<td>CI</td>
<td>0.899, 1.266</td>
<td>0.813, 1.117</td>
<td>0.780, 1.076</td>
<td>0.769, 1.065</td>
</tr>
<tr>
<td><strong>Underweight</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OR</td>
<td>1.048</td>
<td>1.022</td>
<td>0.966</td>
<td>.913</td>
</tr>
<tr>
<td>CI</td>
<td>0.924, 1.190</td>
<td>0.907, 1.50</td>
<td>0.854, 1.093</td>
<td>0.793, 1.052</td>
</tr>
</tbody>
</table>

Notes: N = 6550  Exponentiated coefficients  
Adjusted models include all of the control variables  
*p < 0.05, ** p < 0.01, *** p < 0.001
contribute to a larger reason as to why the child is malnourished. Perhaps the child has a recurring or ongoing illness that requires medical attention or treatment. This illness could be contributing to the child’s nutritional status more than the mother’s mobility status. This may explain why a woman who has higher mobility and goes to a health clinic alone may have higher odds of having a malnourished child than a woman who does not go to a health clinic alone or at all.

The decision-making variable had odds ratios close to one, suggesting that this variable did not have an association with nutritional outcome. This finding is consistent with the findings of Bhagowalia and colleagues’ follow-up study (Bhagowalia, Menon, Quisumbing, & Soundararajan, 2012). However, the absence of a direct association does not undervalue the importance of this variable; decision-making may indirectly be correlated with child nutrition in a way that is beyond the scope of this study.

In the crude model, the variable views-on-violence was statistically significant meaning a woman who condemned violence and never justified it for any reason had lower odds of having a malnourished child. When the controls were added in the adjusted model, the association was no longer significant. After further analysis, it was determined that wealth and education were the primary controls that changed the significance.

In the crude model, a woman who was in an organization and therefore classified as empowered, had higher odds of having a malnourished child than a woman who was not in an organization, which was contrary to the hypothesis. However, in the adjusted model, the direction of the association changed and was consistent with the hypothesis, that a woman who was part of an organization, and therefore empowered, had lower odds of having a malnourished child. Further analysis determined the change of direction of the odds outcomes was due to organization membership picking up factors of wealth. In fact, the majority of the women in these organizations were from the two poorest wealth categories. Wealth may have a stronger impact on the child’s nutrition than organization membership, and further research is necessary to establish the association between these variables.

One of the limitations of this study is the classification of the empowerment variable. This study categorizes individuals for the level of empowerment in a binary manner – either very empowered or not very empowered. It does not differentiate between the various degrees of empowerment (very empowered, mostly empowered, less empowered, and not empowered). This difference in empowerment classification may provide a clearer understanding of the associations between empowerment and nutrition that may not be obvious based on the binary classification of empowerment.

Another limitation is response bias in the way the survey questions were answered. While the survey questions were asked in the privacy of a woman’s home, in some cases, it might not have been possible to achieve a completely private setting. The presence of other individuals such as a husband, relative, or neighbor in the interview vicinity may have led to different responses especially for the more sensitive questions that were used in this study.

Lastly, the population size for wasting was quite small. About 16% of the total child population was characterized by wasting. Since this sample size was small, the results from this analysis may not have been conclusive or accurate, because of variability in responses.

CONCLUSION

It can be concluded that wealth and education overlapped with the construct of women empowerment and independently impact child malnutrition. Indeed these two factors are inputs into women’s empowerment. However, this does not imply that women’s empowerment is not important, but rather its effects on child nutrition are closely linked with the effects of wealth and education on child nutrition. If a woman does not have
the means, accessibility (both physically or financially), or knowledge of resources to provide a nutritious diet for her child, all of which are tied with the construct of empowerment, malnutrition will remain prevalent.

After the 2015 Millennium Development Goals expired, the UN adopted the Sustainable Development Goals, set to expire in the year 2030 (Sustainable Development Knowledge Platform, 2015). The second Sustainable Development Goal elaborates on the gaps of the first Millennium Development Goal and seeks to end hunger, achieve food security, improve nutrition, and promote sustainable agriculture (Sustainable Development Knowledge Platform, 2015). In order to be on target for this goal of ending hunger and improving nutrition, further research is necessary in this area to understand child malnutrition and move forward to attain this Sustainable Development Goal.

REFERENCES


About the Student Authors

Sydney Bohn
is currently an undergraduate student at the University of North Carolina Wilmington, where she is pursuing a B.S. in Environmental Science and a B.A. in Geography, with concentrations in Conservation and Applied Geography. Her main focus and passion is for geographic information science and geospatial technologies. She plans to pursue a career in GIS post-graduation and ultimately hopes to pursue teaching GIS to K-12 students.

Jacob Brooks
is currently a graduate student at the University of North Carolina at Chapel Hill, where he is pursuing his doctoral degree in physics. He graduated from High Point University in December 2015 with a Bachelor of Science degree in physics, with minors in chemistry and mathematics. While pursuing his degree, Jacob worked on computational modeling of biomimetic cilia systems with Dr. Briana Fiser. During his undergraduate studies, he worked as an intern with Becton-Dickinson on HPV assay development in 2014 and at East Carolina University in 2015, where he performed micromixer fluid flow simulations and analyses. During the summer of 2016, Jacob was invited by NASA to work in the Neutral Buoyancy Lab with students testing their projects in the Micro-g NExT program. Jacob also served as a University Ambassador during his time at High Point University, during which he gave tours to and interacted with prospective students and their families. His current graduate research is focused on biomimetic cilia array dynamics.

Andrew Byrum
graduated from the University of North Carolina at Greensboro in May 2016, receiving his B.A. in sociology. He is currently an M.A. student in the sociology department at Columbia University in New York City as well as an affiliated researcher with the Center for Housing and Community Studies back in Greensboro. After the completion of his master’s degree, he hopes to continue on to a Ph.D. program and eventually, a career in social research and academic scholarship. His research interests include the intersection of globalization, collective memory, and the sociology of knowledge as well as theory and cultural sociology.

Emma Caterinicchio
is an undergraduate student at East Carolina University, pursuing a double major in History and Foreign Languages and Literatures, with a concentration in German. She is also completing her Teaching English to Speakers of Other Languages (TESOL) certification from East Carolina. Emma is co-President of the German Club at ECU and is the Outreach Director of No Lost Generation at ECU. She is a new member of the Lambda-Eta Chapter of Phi Alpha Theta History Honor Society and hopes to integrate her studies in and passion for History and languages into her career.

Michael Cantor
is a recent graduate of High Point University, where he was awarded his Bachelor of Science degree in Computer Science. While studying
Derek Detweiler is currently continuing his education at the University of North Carolina Wilmington in pursuit of his Master of Science degree in Marine Science and Policy. His research interests include understanding how coastal wetlands function as important ecosystem service providers for aquatic organisms and humans. Post-graduate school, Derek hopes to have a career incorporating research, coastal management, science communication, and youth education. Previous experiences have placed Derek as an instructor at UNCW’s MarineQuest youth enrichment program, a Teaching Assistant for the UNCW Department of Earth and Ocean Sciences, and a regular at the UNCW Center for Marine Science’s organic geochemistry laboratory. Originally from Bethlehem, PA, Derek spends his time enjoying the outdoors by running, kayaking, hiking, and anything that allows him to appreciate Earth’s beauty.

Samantha Farquhar is studying at the University of North Carolina Wilmington and will graduate in December. She is hoping to earn a B.S. in marine biology and B.A. in international studies with an environmental concentration. Outside the classroom, she has gained valuable experience in the field through her travels and work. She recently completed a semester abroad at the University of Southampton in England where she also took the opportunity to backpack around Europe. In the Caribbean, Samantha led a group of highschoolers in a tropical reef ecology and SCUBA program. This past summer, she interned with the North Carolina Division of Marine Fisheries where she helped sample fishhouses, age and ID fishes, and capture and tag fishes. Samantha also volunteers regularly as diver at the NC Aquarium at Fort Fisher where she helps present dive shows to the public. She hopes to continue her education in graduate school.

Jenna Friday is a senior at Appalachian State University, and is looking forward to graduating in 2017 with a Bachelor of Science degree in Communication, with a concentration in Advertising and minor in General Business. She graduated with honors from Coastal Carolina Community College in 2015, earning her Associate in Arts degree. Jenna’s research interests include college student success, international/intercultural communication, media effects, and representations of race and gender in advertising.

Brian Gottwalt is a recent graduate of UNC Wilmington where he obtained a BS degree with University Honors in Biology and a minor in Psychology. In addition to his studies, he enjoyed competing for UNC Wilmington’s track and cross country teams, and now works as an emergency department medical scribe at Wake Forest Baptist Medical Center in Lexington, NC. He intends to pursue a degree in medicine and aspires to incorporate his interests in skeletal muscle physiology into his future endeavors in the medical field.
Anika Hannan
is currently a graduate student at the Rollins School of Public Health at Emory University, where she is pursuing her Masters of Public Health degree in Behavioral Science and Health Education. She graduated from the University of North Carolina Chapel Hill in May 2016 with a Bachelors of Arts in Global Studies and Public Policy. In addition to her studies in undergrad, she interned at the International Center for Diarrheal Diseases, Bangladesh in Dhaka, Bangladesh and worked as a research intern at the Carolina Population Center and the Lineberger Comprehensive Cancer Center. She plans to continue public health research during her time at Emory.

Matthew Ickowski
is currently an undergraduate student at High Point University, where he is pursuing his Bachelor of Science degrees in both physics and mathematics. Matt currently works with Dr. Briana Fiser answering questions in the field of biophysics. During the summer of 2015 and 2016, Matt worked as an intern with Callaway Golf Company to improve and understand golf ball dynamics and design. He is an avid golfer, and plays for the university’s golf team. He has also been involved in biophysics research with Dr. Briana Fiser. Matt is a brother of Pi Kappa Phi fraternity, and has participated in multiple social and philanthropic events, both on and off campus. After graduating in May 2017, Matt plans to attend law school or graduate school, or pursue a career in industry.

Walter Kearnan
is a recent graduate from the University of North Carolina Wilmington. He graduated with a B.S. in Business Administration with a concentration in International Business, a B.A. in French and a minor in Political Science. He is currently working for Live Oak Bank in Wilmington, North Carolina as an Associate Loan Closing Specialist. He aspires to start a career in government and politics.

Courney Hockett
is originally from Shallotte, NC and is currently an undergraduate student at the University of North Carolina at Pembroke. She is a senior pursuing a bachelor’s degree in Art Education with a focus in Printmaking and a minor in Creative Writing. Courtney enjoys spending her extra time at the North Carolina Museum of Natural Sciences where she works in the Discovery Room as a Weekend Captain; she also works within Exhibits and repairs models throughout the room. Her goal is to become a teacher and achieve important creative and technical skills which will enable her to become a successful visual artist and creative writer.

Chauncey McNeill
is currently an undergraduate student at the University of North Carolina at Charlotte, where he is pursuing a B.A. degree in Chemistry and Criminal Justice, with a focus in Forensics. In addition to his studies, he is working with colleagues in Russia at Southern Federal University to develop supercapacitor materials for renewable energy storage.
He also works for the University of North Carolina at Charlotte’s Student Union as a building manager, supervising 192,000 square-foot building. He desires to continue his education in chemistry, pursuing a PhD in materials science.

Sarah Meyer
is a senior at Appalachian State University and will graduate in May 2017 with her Bachelor of Science in Communication, Advertising, and a minor in business. Her goal is to conduct research to understand how advertising and societies work together and influence one another. She also enjoys the creative aspect of advertising, including graphic design and photography.

Jordan Pearce
is a student at East Carolina University. She is majoring in History and minorining in Pre-Medical Health and Society. Jordan is fluent in Spanish and is a member of East Carolina’s Spanish Club. She is also a member of the Lambda-Eta Chapter of the Phi Alpha Theta History Honor Society and East Carolina’s Health Occupations Students of America Club. Jordan plans to graduate from East Carolina University in May 2018 and go on to attend medical school.

Francesca Quigley
graduated in May 2016 from Guilford College in Greensboro, N.C. with a Bachelor’s Degree in English with an emphasis in writing. She also majored in Women’s, Gender, and Sexuality Studies and minored in Sociology. Quigley hopes to use her education to pursue her dreams of authoring both fiction and nonfiction works. Along with analytical and research based writing, Quigley writes poetry. Her article in Explorations is her first published piece of analytical writing.

Simeon Simeonides
is currently an undergraduate student at High Point University, where he is pursuing his Bachelor of Science degrees in both physics and music, with a minor in mathematics. Simeon is an avid tuba player, performing with multiple ensembles on campus. He has worked at the Joint School of Nanoscience and Nanoengineering (JSNN) on transistor development. He is also working on developing an educational apparatus to better explain system dynamics in different reference frames at High Point University. Simeon is the primary computer aided-drafting (CAD) design and 3-D printing contact at High Point University, and works with several departments to help them with their modeling needs. After graduating in May 2017, Simeon plans to attend graduate school.

Hallie Stidham
is currently a graduate student at Clemson University, where she is pursuing her Master of Science degree in mechanical engineering. She graduated from High Point University in May 2016 with a Bachelor of Science degree in both physics and mathematics. As an undergraduate student, Hallie had the opportunity to work at the European Organization for Nuclear Research (CERN) during the summer of 2015. She worked on computational research projects in particle physics. She also worked with Dr. Briana Fiser on methods of development for biomimetic cilia arrays to be used for experimental testing. During her undergraduate career, Hallie played flute and was a member of several musical ensembles on campus. In the future, Hallie plans to pursue a career in industry.
Alan Vasquez Soto
is currently an undergraduate student at High Point University, where he is pursuing his Bachelor of Science degree in physics. He has been on multiple astronomical observing runs with Dr. Brad Barlow in Chile using the SMARTS telescope system and the 4.1-m SOAR telescope. Alan represents both the Department of Physics and HPU as a University Ambassador, providing tours for and interacting with prospective students and their families. He is also training to become the primary CAD and 3-D printing contact for the department. After graduating in May 2018, Alan plans to pursue an advanced degree in either aerospace engineering or astrophysics.

Sarah Wu
is a graduate of the North Carolina School of Science and Mathematics, where she was highly involved with the Research in Computational Science program. Her interests include mathematical modeling, computer programming, environmental awareness, and science journalism, and she hopes to further explore these areas in college.

Christine Zuelsdorf
is a recent graduate of the University of North Carolina at Wilmington, where she received a B.S. in Biology and a B.A. in Chemistry. While at UNCW she was a Student Ambassador, giving tours to perspective students and a College Mentor where she taught eighth grade students a drug prevention curriculum. She plans to receive a Masters in Biology followed by a Ph.D. Her interest lies within research and hopes to enter the biomedical research field in the future.
About the Faculty Mentors

**Diya Abdo, PhD**
is an associate professor of English at Guilford College in Greensboro, North Carolina. Her teaching, research and scholarship focus on Arab women writers and Arab and Islamic feminisms. Her academic publications include articles in Life Writing, Frontiers: A Journal of Women Studies, Pacific Coast Philology, Image and Narrative, Women’s Studies Quarterly, Eugene O’Neill Review, The Journal of Lesbian Studies and anthologies on Anglophone Arab writers and women writers, including the MLA’s Approaches to Teaching the Works of Assia Djebar. She has also published poetry, fiction and creative nonfiction. Her short story The Love Hoard was nominated for a Pushcart Prize, and her short memoir, Bad Girl, won the Honorable Mention Award for Creative Nonfiction in the Center for Women Writers 2015 International Literary Awards. Her public essays, which have appeared in Jadaliyya, The Feminist Wire and The Electronic Intifada among others, focus on the intersection of gender, political identity, and vocation. She is the founder and director of Every Campus a Refuge, an organization which advocates for housing refugees on campus grounds and assisting them in resettlement. Guilford College has hosted two Syrian families and a Ugandan thus far.

**Sarah Daynes, PhD**
received her PhD in sociology from the École des Hautes Études en Sciences Sociales in Paris, France (2001), and is currently Associate Professor of Sociology at the University of North Carolina at Greensboro. She is the author of Time and Memory in Reggae Music (University of Manchester Press) and Desire for Race (Cambridge University Press). She has also collaborated on a new translation of texts by Durkheimian sociologists in Saints, Heroes, Myths and Rites: Classical Durkheimian Studies of Religion and Society (Paradigm Publishers).

**Wade G. Dudley, PhD**
is a Teaching Professor in East Carolina University’s Department of History, specializing in Naval and North Carolina History. Dr. Dudley holds an MA in Nautical Archaeology (ECU 1997) and a Ph.D. in History (University of Alabama at Tuscaloosa 1999). He is a member of the university’s graduate faculty and advisor to the Lambda-Eta Chapter of Phi Alpha Theta History Honor Society. Professor Dudley’s publications include eight books and several dozen chapters, articles, and short stories. Among the books is Splintering the Wooden Wall: The British Blockade of the United States, 1812-1815, which received a John Lyman Book Award from NASOH.

**Brad N. Barlow, PhD**
serves as an Assistant Professor of Astrophysics in the Department of Physics at High Point University University. He graduated from Mississippi State University with a Bachelor of Science degree in physics and later earned his Master of Science degree and Ph.D. in physics (with a concentration in astrophysics), from the University of North Carolina at Chapel Hill. His research interests include evolved stars, astronomical instrumentation, pulsating stars, and binary interactions.
Scott Juall, PhD
serves as an associate professor of French at the University of North Carolina Wilmington. He is a graduate of Michigan State University and the University of Colorado at Boulder. He is a specialist of early modern European travel narratives and imperialism as well as public art and modernist artistic movements in Paris. He has won numerous awards for both his teaching and mentoring.

Stephen Kinsey, PhD
serves as a professor and graduate coordinator for the Biology and Marine Biology department at UNC Wilmington. He graduated from the Old Dominion University in Norfolk, Virginia with a BS in Biological Science and later earned a MS in Marine Science at the University of South Florida and went on to earn a PhD in Biological Science from Florida State University in Tallahassee, Florida. His research interests are in comparative physiology and biochemistry, with an emphasis on how cellular processes affect complex, whole animal phenotypic traits.

Thomas Lankford, PhD
earned his BS in marine biology from the University of North Carolina Wilmington. He went on to receive MS and PhD in marine biology from the University of Delaware. He completed a postdoctoral research fellowship at Stonybrook University before returning to UNCW in 2000 where he now acts as an associate professor in the department of biology and marine biology and also serves as the Curator of Fishes.

Ai Ning Loh, PhD
is an associate professor in the Department of Earth and Ocean Sciences at the University of North Carolina Wilmington. She graduated from the University of South Carolina with a BS in Chemistry, and a MS and PhD in Marine Science from the School of Marine Science/Virginia Institute of Marine Science at the College of William and Mary in Virginia. Her research group utilizes isotopic and organic geochemical techniques to study the sources, fate and transport of carbon, nitrogen, and phosphorus in aquatic systems.

Thomas S. Mueller, PhD
is currently serving as an Associate Professor at Appalachian State University in the Department of Communication. Dr. Mueller earned a BA in journalism from the University of Wisconsin-Eau Claire, his MBA from Otterbein University, and his PhD in advertising communication from the University of Florida. His academic interests include collaboration on service learning projects with Internet-mediated students in his department’s online advertising degree program, and residence life as part of the faculty in residence program. Dr. Mueller is published in the areas of sport sponsorship, consumer behavior, and involvement models related to psychological perceptions.

Kavita Singh Ongechi, PhD, MPH
is a faculty member in the Department of Maternal and Child Health at the University of North Carolina’s Gillings School of Public Health. She completed her PhD in Population Dynamics with a minor in Epidemiology at the Johns Hopkins Bloomberg School of Hygiene and Public Health. She is also the Senior Technical Advisor for Maternal and Child Health for the MEASURE Evaluation.
project. Her research interests include the evaluation of maternal and child health and HIV prevention programs, and research focused on reaching vulnerable population with interventions.

**Jordan Poler, PhD** is currently an Associate Professor of Chemistry at UNC Charlotte. He received his B.S. degrees in Chemistry and in Physics at the State University of New York, Brockport with a minor in Mathematics. He received his Ph.D. in Physical Chemistry from UNC Chapel Hill in 1992 and then completed an HIH Postdoctoral Fellowship at Princeton University while doing research on Biophysics and new methods with Scanning Probe Microscopy. His research interests are toward the fundamental studies of complex systems at the nanoscale with regard to applications of materials at the macroscale. The Poler Research Group is particularly interested in how large supramolecular systems interact with and ‘Mechanically wrap’ about nanoparticles like carbon nanotubes (SWCNTs, DWCNTs, and MWCNTs), metal nanoparticles (NPs), and quantum dots (QDots). Specifically, we are trying to elucidate energy and charge transfer mechanism between these systems while we work toward efficient manufacturing methods of nanomachines, nanosensors, nanotransducers, nanoparticle based composites, energy storage, and water purification materials.

**Narcisa Pricope, PhD** is an Assistant Professor of Applied Geography at University of North Carolina Wilmington and Director of the Socio-Environmental Analysis Lab. Her work focuses on applied questions at the intersection between land change science, watershed science, and population geography. Dr. Pricope’s overarching research interest revolves around understanding the vulnerability of different populations to environmental change in the context of transboundary-managed water and natural resources by examining the drivers, patterns and impacts of vegetation change and degradation on both ecosystems and people in different parts of the world.

**Jacelyn Rice, PhD** is a postdoctoral associate at Duke University’s Center for the Environmental Implications of Nanotechnology. Her doctorate was obtained at Arizona State University where she defended her dissertation entitled ‘Modeling Occurrence and Assessing Public Perceptions of De Facto Wastewater Reuse across the USA.’ She has worked as an assistant civil engineer at Kimley-Horn and Associates and has held internships with the U.S. Environmental Protection Agency, Pardee Homes, and Southern Nevada Water Authority. To support her graduate studies Rice was awarded three graduate fellowships supported by the National Science Foundation through ASU’s Decision Center for a Desert City, Water and Environmental Technology Center, and GK-12 Down to Earth Science Program.

**Brandon Sanderson, MFA** is a native of Kansas, Brandon Sanderson split his formative years between rural Kansas and Colorado Springs, Colorado. He holds a BS from Colorado State University-Pueblo in Printmaking and Computer Information Systems and an MFA in Printmaking from the University of South Dakota. From 2005 to 2008, he taught at College of the Sequoias and Bakersfield College in California. Since 2008, Sanderson has been at the University of North Carolina-Pembroke where he is now an Associate Professor of Art. He
teaches multiple levels of drawing and all levels of printmaking, including intaglio, lithography, and woodcut. In his time at UNCP, Brandon has organized four national printmaking exhibitions and brought in more than 30 visiting artists. He has also held 17 printmaking workshops at universities in 11 states and participated in over 40 print exchanges. He has also participated in more than 200 exhibitions, including 50 international exhibitions.

**Ann Stapleton, PhD**

is an associate professor at the University of North Carolina Wilmington who serves as the iPlant GWAS/QTL training expert and manages iPlant scientific CI development by UNCW students. Her primary accomplishment is mentoring great research students “students who have become plant breeders, surgeons, biostatisticians, high-school teachers and software developers. Analysis method development and model system development may have more potential to influence how science progresses than specific publications, and data analysis is still slower than it should be. Thus in recent years she has devoted substantial time to helping create the biology cyberinfrastructure for data analysis”democratizing access to computing for everyone, at both large and small institutions, from undergraduates to senior faculty. Not only does she nurture superb science students, she has grown a creative, forward-looking research program. The person who nominated her for the Quantitative Genetics and Genomics Gordon Research Conference Chair position summarized her qualifications as ‘she is a real thinker and she reads the literature’. Recent work in her research group includes the use of factorial abiotic stress treatments to make progress in understanding genotype-environment interaction regulatory architecture, using maize as a model, and the application of ecological statistics and genetics in microbial diversity surveys and metagenomics of leaf-associated microbial communities. She has also collaborated with statisticians on the development of new statistical methods for QTL analysis and curve fitting and with modelers on incorporation of genetic regulatory pathways into crop modeling, along with her ongoing work with computer scientists.

**Aaron Titus, PhD**

serves as an Associate Professor of Physics and Chair in the Department of Physics at High Point University. He received his Bachelor of Science degree from Pennsylvania State University and his Ph.D. in physics from North Carolina State University. He is quite active in the area of physics education, with a focus on effective applications of educational technology. He has served on the board of the American Association of Physics Teachers, co-developed WebAssign with Dr. Larry Martin, and recently co-authored the solutions manual for the 4th edition of the textbook Matter & Interactions.

**Mark R. Wiesner, PhD**

serves as Director of the Center for the Environmental Implications of Nanotechnology (CEINT) headquartered at Duke University. He holds the James L. Meriam Chair in Civil and Environmental Engineering with appointments in the Pratt School of Engineering and the Nicholas School of Environment. His research pioneered the field of environmental nanotechnology and focuses on applications of emerging nanomaterials to membrane science and water treatment and an examination of the fate, transport, and effects of nanomaterials in the environment. He is a 2004 de Fermat Laureate, the 2011 recipient of the Clarke Water Prize, a Fellow of the American Society of Civil Engineers, and a Fellow of the American Association for the Advancement of Science.
Submission Process

Who is Eligible?
The primary author or authors must be undergraduates at a 2 or 4 year college or university in the state of North Carolina working on original research under the direction of a faculty mentor. Works may be co-authored. Students at North Carolina School of Science and Mathematics are also eligible.

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We are seeking research papers, critical essays (literature/research reviews, articles written on a particular topic), or media submissions of performing/fine art endeavors. Text of papers should be no more than 6000 words.

Explorations, the Journal of Undergraduate Research and Creative Activities for the State of North Carolina, provides opportunities for a variety of text and media submissions in the following categories:

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- Humanities
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- Social Sciences
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- Visual Arts and Design

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2. Submit images, graphs, maps, and charts as separate files. For creating graphs and charts (in Excel, Illustrator, or Paint): make the image as LARGE as possible. This will ensure its visibility in the publication. In addition, also save figures as images (.jpg, see below).

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6. Submit everything in its original file. (Example: article as Word .doc, image as .jpg.) Do not convert files. Do not embed images into your article. Be sure you indicate image placement when you submit your final manuscript.

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4. Once your work has been approved by your faculty mentor and reviewed by another faculty member familiar with the research area, you may submit your work yourself or your faculty mentor may submit it. If you are a single author, you will be the main contact. If you are one of multiple authors, decide who will be the main contact and have him/her submit on behalf of all.

5. Proofread, proofread, proofread.

Submission Deadline for Volume XII: June 1, 2017.