

# AUSPEX

Interdisciplinary Journal of Undergraduate Research

## Volume 8

Isa Symancyk | Global Studies

Michael Nowak | Economics

Jenna Joyner | Biology

Isaac Davis | Sociology & Anthropology

Aquilla Sellew | Math

Griffin Harvey | Global Studies

Kaitlyn Zinnecker | Biology & Environmental Studies

Bridget Palmer | History & Political Science

Warren Wilson College  
Swannanoa, North Carolina  
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*Auspex: an augur, or diviner, of ancient Rome who  
watched for omens in the flight of birds*

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## Editorial: Brave Stories for a Hard Time

Noah Hoyle

This journal comes to you after the first hiatus that *Auspex* has taken since its inception nearly a decade ago in 2012. Unless you are an archaeologist in a far flung future where this text is the only proof of human existence, you likely know why that hiatus was taken and do not need it explained to you. In the event that you are a future archaeologist, the facts, in short, are this:

A killer disease prevented any two or more people from meeting each other for nearly two full years in the early 2020s. This severely hampered the production of journals of undergraduate research, and it entirely prevented many other things, some of which make life worth living. Many of us (21st century humans) were unsure whether we could get by without the things we had lost. If I am being honest with you (future historians), our prospects as a species seemed pretty bleak. However, to everyone's surprise, enough of us were able to carry the burden. It was not easy. In fact, for much of the process it was a miserable slog. But an amazing number of us have been able to weather the storm because we (living creatures) are incredibly good at overcoming the odds. The product of that struggle, of that slog, of that Atlasian task, now sits in your hands. After two long years of fighting, we can finally bring you the eight issue of Warren Wilson College's *Auspex* Journal.

If you come from an idyllic future where all strife and conflict has been eliminated, you may be unfamiliar with the feeling of overcoming impossible odds (the feeling that we here at the *Auspex* Team now feel). If this is the case, then you are in luck, because this journal is packed to the brim with stories of groups of people overcoming adversity, or taking stands against overwhelming oppressive forces. Allow yourself (future historian) to live vicariously through the subjects of these papers, and learn what it means to fight your way through bleak scenarios.

In some of these stories, such as Isabel Symancyk's "Defying Gender Norms through Protest Art: The Power of

Feminism in the Fight for Democracy in Chile” or Bridget Palmer’s “No Trucks Moved, By Nobody: The Minneapolis Teamsters Strike and Union Socialism”, the subjects are fighting back against an actively oppressive organization, such as the Pinochet Regime in the former or the Citizens Alliance in the latter. In these stories the adversaries are obvious and the odds are clear. Though their enemies are powerful, the subjects of these pieces refused to give in and fought against their conditions.

In others, the oppressive force is subtler, more of a societal norm than a group of people. These include stigma against immigrants in Michael Nowak’s “Votes Against Migration: Modeling Legislators’ Preferences,” the underrepresentation of women in STEM in Aquilla Sellev’s “Exploring Mathematics through Knitting,” or Appalachia’s reliance on the coal industry in Griffin Harvey’s “Just Transition and a Post-Coal Future for Central Appalachia.” Unlike Pinochet’s dictatorship or the Minneapolis Citizens Alliance, these are problems that we still face today. These papers are less stories about how we have fought against these forces in the past, and more about how we may fight back against them in the future.

Finally, there are papers where just the act of writing them runs counter to an oppressive force. In recent years, some thought-leaders have paraded anti-intellectualism as a core tenet of their ideology, especially in the fields of environmental science, medicine, and history. In times such as these, it may be disheartening to study in those fields, but all over the country, and all over the world, it happens anyway. Despite some pundits wanting indigenous peoples to remain as footnotes in our US history courses, Isaac Davis takes great care and respect when analyzing the techniques used in pottery of the Burke Phase people in his paper “Testing Temper: A Functional and Cultural Analysis of Soapstone Temper in Burke Series Pottery.” Despite ideologues and conspiracy theorists attempting to discredit the results of medical trials, Jenna Joyner is extremely rigorous with the experiments featured in “Effects of Sublethal Imidacloprid on House Cricket (*Acheta domestica*) Neuron Firing Activity

and Chirping Behavior.” Despite many people in power seeming ambivalent to the problem of environmental degradation, Kaitlyn Zinnecker works to combat it in “A Comparative Analysis of Benthic Macroinvertebrate Populations Before and After Stream Restoration in Two Warren Wilson College Streams.” These papers show that Warren Wilson students not only write about perseverance, but persevere themselves.

The authors featured in this journal shine a light on what allowed the human race to survive during these past few years. The early 2020s have been an unfortunate time for just about everyone on the face of the planet, but through our combined resilience, our kindness, and our perseverance, we’ve managed to hold on. We here at *Auspex* hope that, in reading them, you will take some of that spirit with you as you leave.

**“Chancay Urn” by Miles Lamberson**



# **Part One**



**2019 Pieces**

# Defying Gender Norms through Protest Art and the Power of Feminism in the Fight for Democracy in Chile

## Abstract

In September of 1973 the coup of Salvador Allende took place in Chile, bringing the dictator Augusto Pinochet into power for seventeen years until he stepped down in 1990. His dictatorship in Chile involved economic and social repression, as well as great violence which brought fear to the nation. The artistic expression and resilience of arpilleristas in Pinochet's Chile were one of the first forms of resistance against the dictatorship. Arpilleras are wall hangings made of sack material, and were adopted during the dictatorship as a resistance art form that portrayed the Chilean experience under Pinochet. The arpilleristas' role in the re-democratization of Chile emerged due to various factors: the political and economic conditions of the dictatorship, the limits placed on working class women's political activity, the censorship and repression during the dictatorship, and the conflicts experienced by women in their communities. These factors led to the creation of a counterpublic and grassroots movements led by these women. While embroidering arpilleras, these women preserved a counter-historical narrative that contributed to the re-democratization of Chile and continues to remind Chileans that the past informs the present.



## Isa Symancyk

Isa Symancyk graduated from Warren Wilson College in 2019 where she studied Global Studies and worked as a crew leader on the Garden. She is currently applying to receive her Masters in Social Work and working for Homeward Bound in Asheville.

## Introduction

In September of 1973, a military coup overthrew the government of Salvador Allende in Chile, bringing the dictator Augusto Pinochet into power for seventeen years until he stepped down in 1990. His dictatorship in Chile involved economic and social repression, as well as extensive violence. During Pinochet's rule, the Catholic Church created La Vicaría de la Solidaridad (The Vicariate of Solidarity), or simply the Vicaría, a solidarity group that organized soup kitchens, provided legal guidance, and eventually created the arpillera workshop model for working class communities most affected by the dictatorship.

Arpilleras are wall hangings or tapestries made of sacking material, which were adopted by Chilean artists during the dictatorship as a form of resistance art that portrayed the Chilean experience under Pinochet. This thesis will celebrate this form of artistic expression, and will discuss the resilience of the arpillera-makers (arpilleristas) in Pinochet's Chile as well as the dominant narratives regarding arpillera-makers, both domestically and internationally. I will explore how these narratives have affected the evolution of the arpilleras as an art form in post-dictatorship Chile and how feminist sociological theory allows us to better understand the role of arpilleras in the re-democratization of Chile.

The arpillera-makers' role in the re-democratization of Chile emerged due to four main factors: the political and economic conditions of the dictatorship, the limits placed on working class women's political activity, censorship and repression during the dictatorship, and conflicts experienced by women within their communities. These factors led to the creation of a counterpublic and grassroots movements led by these women. The modern arpillera-makers who practice today are still concerned with protesting the repression imposed on them by the government, but they also focus on preserving *la memoria* (the memory) of the dictatorship and its atrocities. For them, memory is fragile and can be manipulated by popular ideologies and politics, and

it is important to the arpilleristas that their experiences and memories are preserved for the next generation. The arpilleristas manipulate the dominant cultural narrative that women cannot create political change in the public sphere by making arpilleras in a counterpublic space dominated by marginalized women. While embroidering arpilleras, these women preserved a counter-historical narrative that contributed to the re-democratization of Chile and continues to remind Chileans that the past informs the present.

Nancy Fraser's concept of the "counterpublic sphere" is important in understanding the arpillerera workshops and their organization. In Jürgen Habermas's *Structural Transformation of the Public Sphere*, he defines the public sphere as "society engaged in critical public debate."<sup>1</sup> He emphasizes the importance of the public sphere in its role as a check on the state's power, in contrast to the private sphere, which he defines as relating primarily to the family and household. In *Rethinking the Public Sphere: A Contribution to the Critique of Actually Existing Democracy*, Fraser critiques the limitations of Habermas's theory, emphasizing that his definition of the public sphere disregards the fact that this space is not accessible to women or other marginalized groups, and that it is instead "the arena, the training ground and eventually the power base of a stratum of bourgeois men who were coming to see themselves as a 'universal class' and preparing to assert their fitness to govern."<sup>2</sup> The Habermasian public sphere is associated with men, whereas private domestic spheres are expected to be inhabited by women. This distinction between public and private spheres isolates the issues that usually affect women, such as reproduction, child and family care, and household management.

Fraser argues that in response to this isolation, marginalized groups form their own public sphere, which she calls the "subaltern counterpublic." Counterpublics function

1. Jürgen Habermas, *The Structural Transformation of the Public Sphere an Inquiry into a Category of Bourgeois Society*, (Cambridge: Polity, 2015), 52.

2. Nancy Fraser, "Rethinking the Public Sphere: A Contribution to the Critique of Actually Existing Democracy," *Social Text*, no. 25/26 (1990): 60.

as spaces for discussion and grassroots organization and act as “training grounds for agitational activities directed toward wider publics.”<sup>3</sup> Oppressed and marginalized groups can then create public change by organizing in the counterpublic. The economic difficulties exacerbated by Pinochet’s regime led to women’s collective action within the arpillera workshops to create a counterpublic space for political dialogue and organization against the dictatorship. The arpilleristas’ counterpublic created a new political role for women and was crucial to the re-democratization of Chile.

The fear of detainment, torture, and disappearance, as well as the growing economic disparities under Pinochet compelled working class Chilean women to simultaneously fulfill the traditional expectations for women and violate them by becoming politically active in counterpublic spaces. These spaces provided safety for women to discuss the issues they were facing without men present, and provided an atmosphere for learning and engaging in politics. These women were also insulated from the public sphere, where men were in closer contact with visible struggles for power and were thus more vulnerable to the violence of the dictatorship. The lack of men in households and the women’s growing motivation to find their missing loved ones required women to organize within their feminine roles, in the domestic counterpublic, where they harnessed their power and identity as women to create political change.

## **Methodology**

I gathered my primary data during six months studying abroad in Chile. I stayed in Valparaíso, the second largest city in Chile, where I attended a local university and lived with a host family. For three months I attended arpillera workshops with the group Arpilleras: Sitios de Memoria Valparaíso (Arpilleras: Sites of Memory in Valparaíso) and conducted participant observation. The group meets weekly in PRAIS, a community building that

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3. Fraser, “Rethinking,” 68.

hosts artistic workshops and community activities. The group was formed around four years ago and is made up of around twenty women, although the number of women who attend fluctuates from week to week. The women's ages range from late forties to early seventies, and the majority of them are married and have children or grandchildren. During the dictatorship all of them were involved in leftist protest movements, and some were directly involved in communist groups or were married to someone who was. All of them were deeply impacted by the violence of the dictatorship; they were detained, imprisoned, tortured, and/or exiled. A few of them were actively making arpilleras during the dictatorship, but the majority of them got involved in making arpilleras after the dictatorship ended.

The research I gathered with Arpilleras: Sitios de Memoria Valparaíso includes my attendance of their workshops once a week for three months, one-on-one interviews, documentation of their exhibitions, and access to the physical archives of their finished arpilleras and artist statements. To continue analyzing the importance of the national and international narratives of the arpilleras, I examined resources from both Chile and the United States including newspaper articles, museum exhibitions, and digital archives to further understand what kind of media outlets were and are discussing the arpilleras and their significance. The online databases of arpilleras are minimal, and the images I have of arpilleras mainly come from my primary research conducted with the arpillera workshop in Valparaíso. The newspaper articles cover a large timeframe and leave me with questions about why the arpilleras' impact was discussed only after Pinochet's dictatorship began to fall, and why interest in arpilleras is resurging in contemporary times.

To interpret this data, I use feminist analyses of the counterpublic as a space for discourse among marginalized women, and of arpilleras' utilization of their roles as mothers to gain access to the public sphere and incite political change in Pinochet's Chile. The feminist perspective allows me to reflect

on the complexity of the political movement that shaped the arpillera workshops and political activism under Pinochet's dictatorship. I found that the artistic expression of the arpillera is discussed domestically and internationally as an aspect of post-dictatorship Chilean nationalism, yet the role of arpilleras in preserving a counter-narrative of Chile is largely ignored. I argue that the genderedness and perceived innocence of the domestic sphere allowed the arpilleras to become catalysts for protests and revolutionary acts in Chile during the dictatorship.

### **Scholarly Approaches to Art, Religion, Protest and Women's Counterpublics in Chile**

The Catholic Church has had a complex relationship with the arpillera-making process. The Church both served and challenged the government. It created a counterpublic space for arpilleras, but controlled their creative expression. The Vicaría, the human rights organization connected with the Church, employed the arpilleras but regulated their work in a way that counteracted the revolutionary potential of the arpilleras.

Jacqueline Adams' *Art Against the Dictatorship: Making and Exporting Arpilleras Under Pinochet* discusses arpilleras using qualitative research and participant observation. She conducted interviews with the Vicaría's staff and the arpilleras themselves and compiled an archive of photographs of arpilleras. Adams analyzes the significance and use of the arpilleras among working class women during and directly after the dictatorship. She discusses the evolution of arpillera-making as a grassroots movement and the consumer chains involved in the transnational sale of arpilleras. She clearly describes how the arpillera workshops began and how they functioned, as well as their relationship to the church and to both national and international consumers.

The Vicaría was the primary exporter of arpilleras, so they had total control over what the arpilleras could portray. If an arpillera was deemed too denunciatory or not denunciatory enough, the pieces would be sent back to the artists, who would

not be paid. Over the course of the dictatorship, the Vicaría's stance on what was "too denunciatory" changed with the shifting political tensions in Chile. The Church's control over the content of the arpilleras allowed them to modify the dominant narrative of the Chilean dictatorship, making it difficult for the arpilleras to preserve their counter-narratives.

Adams' work illustrates the complexity of the system of arpillera creation and distribution by showing how the Church's exportation of arpilleras modified the counter-narratives of the art form by catering to consumer desire, while simultaneously providing the women with a working wage. Due to the danger that protesters faced during the dictatorship, the Church was the only organization that could provide relative safety for these women. If a woman made an arpillera that was deemed inappropriate or too bold, the Vicaría felt justified in rejecting her arpillera and not providing pay. Many women were the primary financial providers for their families, so the implication that arpilleras could not document their experiences truthfully without risking a month of no pay carried significant weight. The threat of financial precarity shaped their counter-narratives and perpetuated certain ideas about what arpilleras should be.

Lynn Stephen's book *Women and Social Movements in Latin America: Power From Below* explores six cases of women's grassroots organizations in Mexico, El Salvador, Brazil, and Chile. She utilizes Fraser's conceptualization of the counterpublic to discuss how the women involved in these grassroots movements created their own counterpublics to enact change in their workplaces. She also digs into these women's "informal" work, which allowed them to maintain their domestic roles while working part time. Stephen's text, like Fraser's, concerns the dichotomy between public and private spheres, suggesting that the formal economy is public, male, and legitimized, while the term "informal" suggests illegitimacy and marginality and is associated with the domestic, private sphere.

Stephen found that the dominant cultural ideologies in South America conceptualize women's role as confined to

domestic and private spheres. These ideologies have been an obstacle to women's efforts to organize politically. It is frowned upon for women to engage in politics, and only upper class women have the luxury to do so. Stephen's research in Chile focused on the Inte Industry Union of Seasonal and Permanent Workers of Santa María, Chile, one of the first successful labor unions for seasonal laborers after Pinochet. Because of their dominant presence in the workplace, women provided most of the leadership for this union. Stephen found that the women's political activism was sparked by situations in their daily lives in which their voices were not treated equally. The women of Santa María, similar to the arpilleristas, slowly created a grassroots movement that confronted the inequalities they faced. The women found ways of resisting these inequalities by redefining their marginality and creating a safe counterpublic space for political discourse.

Stephen analyzes Mothers' Centers in Chile both before and during the dictatorship. The Mothers' Centers were community centers for women to learn traditionally feminine crafts like sewing, weaving, and knitting, as well as other household tasks. However, during the dictatorship the centers became focused "on the role of women as the reproducers of future soldiers and as housewives." They served, essentially, as "a mouthpiece for the military to promote women's duty as mothers to defend the integrity of the Chilean family and to save the fatherland."<sup>4</sup> Women were defined in biological terms and reduced to mothers and caretakers at the service of their husbands and the nation. The dictatorship's definition of women as solely reproductive objects led to the overlooking of the women's activism during the dictatorship, as the authorities believed that their movements were naive and could not incite political change. The arpilleristas took advantage of their portrayal as helpless, suffering mothers, and developed their political power out of the government's sight.

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4. Lynn Stephen, *Women and Social Movements in Latin America: Power from Below* (Austin: UT Press, 2000), 248.

*Social Responsibility in the Global Market: Fair Trade of Cultural Products* by Mary Ann Littrell and Marsha Ann Dickinson discusses the processes and goals of fair trade organizations during the late twentieth century. Although they do not specifically discuss arpilleras, their research provides important insights into fair trade organizations' interactions with artists, their priorities, and how they market artwork to customers.<sup>5</sup> During the earlier years of the dictatorship the Vicaría sold arpilleras to nongovernmental organizations (NGOs) primarily interested in supporting the humanitarian crisis in Chile. But between the mid-eighties and mid-nineties the arpilleras' consumer base changed due to international political shifts and the lack of concern for a newly democratic Chile, and arpilleras began to be sold through fair trade organizations.

While the economic support provided to these women by the Vicaría through both NGOs and fair trade shops was incredibly valuable, it also reinforced Stephen's concepts of informal and illegitimate work due to the treatment and regulation of the women in the workshops and their lack of control of subject matter due to the commercialization of the arpilleras in later years. Furthermore, by being forced to adapt to the fair trade shops' desires, the arpilleristas' documentation of a counter-narrative of marginalized women in Chile was manipulated for profit.

The fourth source that informed my perspective about the arpilleristas and their relationship to the Vicaría and Catholic Church is Brian Smith's *Church and Politics in Chile: Challenges to Modern Catholicism*. Most of the research I have encountered praises the Church for their support of the communities repressed under Pinochet, but Smith discusses the Church's change in politics and leaders throughout the dictatorship in a way that illuminates the negative aspects of the Church's involvement with the arpilleristas.

Although the Church provided support for those afflicted

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5. Mary Ann Littrell and Marsha Ann Dickson, *Social Responsibility in the Global Market: Fair Trade of Cultural Products* (SAGE Pubs, Inc., 1999), 4.

by the violence of the regime, it felt that it wasn't safe to publicly oppose the regime. Smith discusses the Church's hesitancy to address the humanitarian concerns at the heart of resistance to the dictatorship, and how it waited a year after the coup in 1974 before using the Church's immunity to speak out against Pinochet. When the Church finally made a statement about the dictatorship, it stated that it was "not called upon to install governments or to take power away from them, nor to give or withhold recognition of governments," yet it was compelled to take on "the task of reconstructing Chile and of removing the great difficulties in which the country now finds itself."<sup>6</sup> The Church's total control over the export and creation of arpilleras, along with the arpilleras' financial precarity, allowed the Church to dictate their wages, expression, and thus the creation of an artistic counter-narrative as a whole.

While there are abundant sources on the Chilean arpilleras during and after the dictatorship, little research has been done on why and how the narrative of the artistic expression and resilience of arpilleras in Pinochet's Chile is celebrated domestically and internationally in the context of post-1990 Chilean nationalism. Overwhelmingly, contemporary discourse portrays arpilleras through the tragic but scripted lens of struggling mothers, and praises them for their raw emotion and bravery. I believe that the commodification of arpilleras over time was possible due to their makers' identities as marginalized mothers in the private sphere. Their status as marginalized women and mothers delegitimized their work, making it easier for the Church and fair trade organizations to manipulate the women's narratives and erase some of their political agency. Yet their status as suffering mothers also piqued empathy and consumer interest, and helped them to protest publicly as women and bring women into the public political sphere.

The final source that I will discuss is Marjorie Agosin's *Tapestries of Love, Threads of Hope*, which shows more specifically

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6. Brian H. Smith, *Church and Politics in Chile: Challenges to Modern Catholicism*, (Princeton: Princeton Legacy Library, 2014), 315.

how the arpilleristas created a counterpublic sphere and were able to create public change via counterpublic discourse. Due to the strong belief that women were objects of reproduction for the military state, women were discounted as viable organizers for protest. However, by utilizing their identities as mothers, women had the opportunity to take on unique political roles due to “disappearances” and the detainment of their male family members. Because of the loss of their family members, many women took to searching for them themselves, and they met each other while searching at prisons, police stations, or the soup kitchens provided by the church.

Agosín discusses how the arpillera workshops became important counterpublic spaces that helped women to understand what was happening politically as they gained independence by becoming the primary providers for their families. She interviews an arpillerista named Amparo, who states that “the Chilean woman is playing the main role in the family today and has also had to assume the role of provider for the family. Because of her double responsibilities, changes have been made.”<sup>7</sup> Agosín finds that the arpilleristas’ role in returning democracy to Chile was so powerful that the “military themselves made the comment that the biggest mistake they made was in leaving the family members of the disappeared alive.”<sup>8</sup>

While this empowerment contributed to the fall of Pinochet, it also allowed for women to continue to empower themselves after the dictatorship because the arpillera workshops had become a place for the arpilleristas to assume “a new identity that added an important dimension to their traditional female role.”<sup>9</sup> In the workshops, women began to educate themselves about politics and became empowered. After the return to democracy this empowerment continued to affect Chilean politics and daily life as this experience encouraged women to integrate themselves into the public sphere and document their

7. Marjorie Agosín, *Tapestries of Hope, Threads of Love: The Arpillera Movement in Chile* (Lanham, MD: Rowman & Littlefield Publishers, 2008).

8. Agosín, *Tapestries*, 19.

9. Agosín, *Tapestries*, 22.

counter-narratives in order to resist the dominant narratives about the dictatorship.

## Discussion

I conducted participant observation and interviews with the arpillera collective Arpilleras: Sitios de Memoria Valparaíso. The group's meetings are opportunities for the women to remember their lived experiences during the dictatorship, share those experiences with a supportive community, discuss their frustrations about the current political climate in Chile, and talk about their families and events happening in their lives. The workshop is also a time for women to work on their arpilleras and to give each other advice about their work. Most of my interviews were conducted one-on-one and involved questions about how the interviewees learned of the arpilleras, how they got involved in making them, what making arpilleras means to them, and the technical process of making an arpillera.

As I worked with the arpilleristas I began to notice the importance these women placed on their role in preserving the memories of those who suffered the violence of the Pinochet dictatorship and continue to suffer violence in the present. In every interview the women mentioned their motivations to preserve the historical memory of Chile for future generations. They document specific sites of detention and torture, which would otherwise be forgotten. The arpilleristas hope that through their work with the arpilleras and by reaching out to the younger generation, their lived experiences during the dictatorship will be remembered, which will prevent a future dictatorship from happening.

Their artist statements further reiterated that the arpilleras serve as a living memory of the dictatorship. Marisa's arpillera "La Escuela Barros Luco" (The Barros Luco School) illustrates the military's use of schools as detainment centers. In her artist statement Marisa said that she wanted "to capture the situation experienced by two university students, Marcela López and Orlando Juantock, who... helped to organize the resistance

movements in Valparaíso. They were arrested and detained here on September 12, 1973.”<sup>10</sup>

This arpillera portrays the military’s overtaking of the Technical University of Santa María and the burning of books while the students watch from inside the school.<sup>11</sup> Marisa’s arpillera makes a clear connection between the education system and its perpetuation of the dominant narrative both during the dictatorship and in the present. Her artist statement reminded me that the basement of the university I attended, Pontificia Universidad Católica de Valparaíso, was used to detain students during the dictatorship. The university does not acknowledge this history and I would not have known that this happened if the arpilleras had not told me about it. Marisa’s depiction of burning books represents the educational systems’ erasure of history, knowledge, and the memory of the violent dictatorship.

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10. Guillermo Correa Camiroaga, “Arpilleras: The Language of Popular Art in the Rescue of Historical Memory,” *Resumen Newspaper*, April 5, 2019.

11. Marisa’s arpillera “La Escuela Barros Luco,” embroidery, in Correa Camiroaga, “Arpilleras.”



Another arpillera I accessed in their archives is called “Two Women Looking for Their Families” by Johana de la Fuente.<sup>12</sup> Johana describes this arpillera as “a mother and a daughter, or a companion, searching for their missing family member.” During the dictatorship many men were abducted and detained in detention centers whose locations were not disclosed to the men’s families. In the beginning of the dictatorship, families of detainees spent a lot of time trying to locate these detention centers. This particular arpillera illustrates a detention center called Silvia Palma. Johana’s emphasis on the women affected by the dictatorship and their experiences searching for loved ones is another example of the counter-narrative expressed through the arpilleras, and of use of arpilleras as documents that commemorate the experiences ignored by the government’s narrative of Chilean history.

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12. Johana de la Fuente, “Two Women Look for Their Families,” embroidery, Arpilleras: Sitios de Memoria Valparaíso.



These arpilleristas continue to produce arpilleras long after the dictatorship, partly as a way for them to process the loss of their loved ones. The arpilleras are powerful artifacts that recount the survivors' lingering grief about the experiences of their missing family members, in addition to preserving their counter-narrative. The arpillera "A Friend Moved" made by Valeria Arancibia Jerias details the experiences of her father who was kidnapped, detained, and tortured in the Silva Palma barracks in Valparaíso.<sup>13</sup>

It depicts her father lying on the ground after being tortured, with a figure at his side comforting him. Valeria's artist statement reads: "After the torture I found him lying in a corner, the only thing I could do was clean the saliva from his mouth."<sup>14</sup> This arpillera reminds the viewer that the violence used during the dictatorship is passed down through generations and will continue to damage Chilean people if it is forgotten.



13. Valeria Arancibia Jerias, "A Friend Moved," embroidery, Arpilleras: Sitios de Memoria Valparaíso.

14. Valeria Arancibia Jerias, "A Friend Moved," artist statement, Arpilleras: Sitios de Memoria Valparaíso.

The modern arpilleristas and those active during the dictatorship both play a vital role in maintaining democracy in Chile by creating counterpublic female spaces that give voice to the counter-narratives of those oppressed by the dictatorship. The women emphasize the vital role of documenting these narratives and emphasize that their memories are a fundamental part of the collective history of Chile. During my interview with Maria Alicia Salinas, one of the few women in the group who made arpilleras in workshops provided by the Vicaría, she spoke about the importance of passing on the arpilleras to the younger generation: “I’m old now and I have little time. So we need to rescue everything that has happened here. We need to pass the memory and keep the memory alive.”<sup>15</sup> For Maria and the other women involved in the workshops, arpilleras are an effective method of educating youth about the dictatorship. The arpilleristas express their collective memory through their arpilleras and bring their counter-narratives to the public in an accessible way. As Maria said later in the interview, “The arpillera is not a violent form of protest. On the contrary, it is one of the things that you can see and you can easily coexist with.”<sup>16</sup> By utilizing a craft that has been passed down from their mothers, the arpilleristas, both present and past, successfully made their counter-narratives known nationally and internationally.

While I was in Chile I visited El Museo de la Memoria y los Derechos Humanos (The Museum of Memory and Human Rights). The museum was opened in 2010 and is dedicated to preserving the memory of the dictatorship. It is free for all visitors and walks you through the days leading up to the coup and what transpired afterwards. It provides a detailed account of the atrocities that occurred under Pinochet, giving the locations of the numerous detention centers throughout Chile as well as testimonies of the victims. It documents the various protests that occurred during the dictatorship and includes details on the process of re-democratizing Chile.

15. “Interview with Maira Alicia Salinas,” interview by author, November 10, 2018.

16. “Interview with Maira Alicia Salinas.”

I went to Santiago for the weekend to visit this museum because I had heard that it featured arpilleras. Excited to learn what the museum had to say about the arpilleras and protest art, I wandered through the exhibitions looking for arpilleras, but gradually grew discouraged when they seemed nowhere to be found. Finally, on the third floor and in a separate part of the museum, I came across the arpilleras at the end of a long hallway. It was a small exhibition with eight arpilleras, accompanied by titles and descriptions. It told how the arpillera workshops were formed through the Vicaría and how they spread across Chile. It introduced arpilleras as “[playing] an essential role, documenting testimonies, customs, and experiences of the social process that Chile experienced during the dictatorship.”<sup>17</sup> Although I had the chance to photograph these arpilleras and read the museum’s descriptions of them, I learned more from the way the museum framed them: they were spatially isolated, far removed from “real art,” and although they were highlighted as important pieces of testimony, they were not recognized as tools to create political change.

The museum’s downplaying and isolation of arpilleras reinforces the idea that they belong to the private, domestic sphere. This disconnect between the museum’s mission of preserving the memory of the dictatorship and their lackluster presentation of arpilleras contributes to the erasure of the arpillera’s counter-narratives. The museum fails to utilize the full potential of the arpillera as an accessible way to learn about the history of the dictatorship. In an arpillera, memories of detainment, torture, and the search for loved ones are transformed into colorful scenes that seem innocent until closer examination by the viewer. Arpillera Cecilia Araneda told me that “When you make an arpillera you are telling a terrible story .... although the story is terrible, the way we tell it makes it more accessible to people. The arpilleras bring people closer to history.”<sup>18</sup>

17. Museum label for artwork, Arpilleras, Santiago, Museo de la Memoria y Derechos Humanos.

18. “Interview with Cecilia Araneda,” interview by author, September 24, 2018.

Although the military dictatorship has passed, the military still has a lot of political power in Chile and offers some of the best paying jobs. The National Truth and Reconciliation Report, written by the Chilean government in 1991, claimed that Chile had recovered from the dictatorship. It did acknowledge the harm done by Pinochet to the Chilean people, stating that the National Intelligence Directorate (DINA) was responsible for the 3,428 cases of disappearance, killing, torture, and kidnapping.<sup>19</sup> But Pinochet was able to pass an amnesty law, Decree Law 2191, which prevented him and his officers from being prosecuted for their crimes against humanity. The military still has a lot of influence on the government, and many of the military officers involved in the dictatorship were not penalized for their violence. The arpilleristas and other leftists I met still associate the army with the dictatorship's violence and right-wing politics.

Every year on September 11, the same day of the military coup, people march throughout the cities of Chile to remember the violence of the dictatorship. The host family I lived with is rather conservative and worked for the army in the years after the dictatorship. My host father was adamant that the marchers are violent and that “they need to let go of the past.”<sup>20</sup> He also referred to those who continue to protest as “comunachas,” which translates roughly as “big communists,” and claimed that Pinochet improved the economy. His opinions exemplify a divide between those who want to preserve the memory of the dictatorship as a way to not repeat the past, and those who feel more comfortable ignoring the history of their country due to their support of the regime or because they weren't directly affected by its violence. For the latter group, the hardships of the dictatorship passed out of memory once Chile became re-democratized.

Gabriela Bailleras, another arpillerista, told me that their work was concerned with “maintaining the idea that the coup

19. “Truth Commission: Chile 90.” United States Institute of Peace. October 02, 2014.

20. “Interview with Mauricio and Tita,” interview by author, September 11, 2018.

d'état continues because there are still many comrades who are alive, and we have been violently touched by the situation that occurred in 1973.”<sup>21</sup> My host parents experienced the anxiety of living during a military dictatorship, but did not experience violence first hand. My host mother said that “me and [my husband] were in our twenties at the time, and we didn't feel afraid. We would still go out and meet up with our friends at the bars.” However, both my host parents admit that they are more conservative and could be considered middle class. Many of the arpilleristas who were actively protesting the dictatorship and were involved in leftist movements were from working class families and were constantly exposed to the violence and fear of the dictatorship.

It is understandable that those who were protected from the violence of the dictatorship or even supported Pinochet want the dictatorship to be forgotten. But what about the three thousand missing people and the families of those people? As Gabriela argues, “It is important now to keep the memory of what happened, in this moment we have a rightist government in power, and people are still being killed, the repression has not stopped.”<sup>22</sup> The collective memory of what happened during the dictatorship, according to the arpilleristas, needs to be preserved to prevent future violence. The memory of Pinochet is fading, however, as families like my host family pass down their narrative of the dictatorship to their children and grandchildren, and those affected by the violence are not compensated or acknowledged. My host family's grandchild might only learn of the dictatorship in school, where the master narrative of the dictatorship is likely to be perpetuated. My host family, like many others who were not directly impacted by the violence of the dictatorship, have the privilege to forget the past. The arpilleristas, though, have worked for decades to keep their stories from being forgotten.

Marie Porter's *Mother-Texts: Narratives and Counter-Narratives* discusses the damaging effects of master narratives.

21. “Interview with Gabriela Balleras,” interview by author. November 3, 2018.

22. “Interview with Gabriela Balleras.”

Although her work does not directly intersect with arpilleras, she highlights the inherent oppression present in a master narrative of history. She states that women's counter-narratives highlight "the inadequacy of the master narratives" and "reveal how problematic master narratives can be."<sup>23</sup> During the dictatorship, the arpilleras preserved and recorded their counter-narratives, which resisted the government's master narrative. They did this through their use of the counterpublic – resisting by working within their expected gender roles and partaking in domestic crafts. Often, the Chilean women living during the dictatorship who documented their experiences and memories were the only ones left in their families who could discuss the violence that their family members had faced.

I gathered newspaper articles and advertisements disclosing information on exhibitions of arpilleras and their protest movements in Chile. The time period in which arpilleras gained the most coverage in the US was the mid-eighties, and from 2016 to the present. I believe this is due to the US's political influence on the dictatorship in Chile and its avoidance of taking responsibility for the violence that took place in Chile during that time. In addition to the US sources, I accessed a newspaper article published by the Chilean newspaper *Resumen* which covered an exhibition by the arpilleras of the Arpilleras: Sitios de Memoria Valparaíso group and includes quotes from the opening statements made by the women. I found that the language and focus when discussing the arpilleras and their protest art varied greatly between Chilean sources, the artists' explanations of their work, and international media.

The newspapers in the US that covered arpilleras in the mid-eighties were *The New York Times*, *The Washington Post*, and a newspaper based in Charlotte, North Carolina. These articles were brief, under the "art" and "home and garden" sections, and gave a description of the arpilleras as "folk art wall hangings" and "craft." A more lengthy article in *The New York Times* is titled

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23. Marie Porter, *Mother-texts: Narratives and Counter-narratives* (Newcastle: Cambridge Scholars, 2010).

“Chile’s Women Use Protest Message in Folk Art Hangings,” and includes interviews with Anitta, an arpillerista and member of the Vicaría of Solidarity. She describes her life and how it was deeply affected by the dictatorship: “I began to make arpilleras, small colorful wall hangings that tell of the hardships, and sometimes the joys, of daily life in Chile... [she] recounts her struggle to give her son an education, his success as an engineer, his arrest, her long, futile and ongoing search for him.”<sup>24</sup> At the end of the article there is an address for Americans to write to the Vicaría of Solidarity to buy arpilleras. However, more often these articles focus on advertising local exhibitions of arpilleras – framing them as sources of aesthetic pleasure and consumption rather than political acts.

In *The Washington Post*, an article was published in 1989 right before Pinochet stepped down as dictator. The article is titled “Furor Over Photos; Controversy Over Hispanic Exhibit” and discusses an art exhibit opened during National Hispanic Heritage Week that was censored by the General Service Administration (GSA) due to their dislike of the political themes found in the art. The acting director of the Office of Civil Rights for the GSA, William Richardson, said that “some of the material was politically sensitive.”<sup>25</sup> But several of the exhibit’s artists defended their work, saying that their pieces portrayed “the reality of Latin America.”

Many photographs of poverty and violence were taken down by the GSA in what was presented as a diplomatic issue. The GSA allowed for the arpilleras to remain in the gallery, but took away the explanations of the images that accompanied them. Peter Masters, the head of graphics for the GSA, said, “We’re talking about a country we have diplomatic relations with... If you were a representative of that embassy and you saw that, wouldn’t you hightail it over to the State Department and complain?”

This newspaper article by *The Washington Post* was one of the

24. Marvine Howe “Chile’s Women Sew A Protest Message In Folk Art Hangings,” *New York Times*, November 14, 1984.

25. Carla Hall, “Furor Over Photos; Controversy Over Hispanic Exhibit,” *Washington Post*, 1989.

few that addressed the controversy of the arpilleras. The GSA's hesitancy to showcase their descriptions demonstrates that even internationally the arpilleras have the ability to create political change and uproar. The arpilleras were deemed appropriate to stay in the exhibition without their descriptions because of their association with domestic craft. Without the descriptions, though, the images had less power to create change.

The US newspaper articles focus more on the tragedy of the arpilleras' experiences by using the words "folk art,"<sup>26</sup> "pictorial appliques,"<sup>27</sup> and "controversial"<sup>28</sup> in their titles to describe the arpilleras. Within the article the words "struggle," "futile," "bittersweet," and "hardship"<sup>29</sup> describe the women's search for their loved ones during the dictatorship. In contrast to the articles in the North American press, which do not mention the preservation of memory, a Chilean article titled "The Language of Popular Art in the Rescue of Historical Memory"<sup>30</sup> does not equivocate in emphasizing the use of arpilleras in preserving the counter-narratives about the history of the dictatorship in Chile. The Chilean article also includes quotes from the artists instead of attempting to evoke a sympathetic response from the reader as the US articles do. While sympathy could potentially contribute to the mobilization of a national and international response to military violence, the US articles don't recognize the arpilleras themselves as catalysts for political change, nor their role in articulating the counter-narratives of the dictatorship.

The largest online databases displaying arpilleras are Chilean and include the National Library of Chile, the Documentation Foundation and Archive of Vicaría de la Solidaridad, the Museum of Memory and Human Rights, and The *Resumen* news site. While the Chilean resources emphasize the importance of the arpilleras in maintaining a counter-

26. Howe, "Chile's Women."

27. M. L. Emblen, "New Jersey Guide," *New York Times*, September 24, 1989.

28. Hall, "Furor Over Photos."

29. Howe, "Chile's Women."

30. Correa Camiroaga. "Arpilleras."

narrative of Chilean memory, descriptions and photographs of the arpilleras are hard to find on these websites. The disparity of information provided by Chilean sources is not surprising considering the association of women with the private sphere and the government's ignorance of women's ability to manifest change in private spheres. While the arpilleristas were the first to protest publicly against Pinochet, they are in some circles still invisible to the master narrative and continue to go unrecognized although they succeeded in fighting the ignorance of the dictatorship. I will explore the lack of recognition of arpilleras in the following Chilean sources.

The National Library of Chile has definitions of the Vicaría and provides a brief description of arpilleras as a means provided by the church for women to denounce the atrocities that occurred under Pinochet's dictatorship and the hardships experienced by the women and their families. Along with the description there is a small archive of photos of arpilleras in black and white provided by the Vicaría. The only description provided underneath the photos says that they were made in 1989. This does not acknowledge the political role the arpilleras have played in preserving the memories of the oppressed during the dictatorship and does not shed light on the counterpublic created by working class women in an attempt to bring justice to their loved ones.

The Vicaría website, "The Documentation Foundation and Archive of Vicaría de la Solidaridad," states that its purpose is to document "originals and copies of court files, trials for political crimes... kidnappings, disappearances, torture, testimonies and... denunciations."<sup>31</sup> The database contains around 1,400 photographs of various movements sponsored by the Vicaría during the dictatorship. However, even though the arpillera workshops were sponsored by the Vicaría, I had to dig to find any photos or descriptions of the arpilleras on their site. Altogether there are thirteen photos of the arpilleras; no context or descriptions of the arpilleras are provided. The lack

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31. La Fundación de Documentación y Archivo Vicaría De La Solidaridad.

of commemoration of the arpilleras by the Vicaría themselves shows us that although the Vicaría is credited with starting the arpillera workshops, it does not care to remind Chileans of the political impact the women had on protest movements in Chile.

The Museum of Memory and Human Rights' website provides four visual representations of arpilleras along with a description of their contents. Two of the arpilleras are under the category of "infancy" and depict happy childhood scenes in the countryside and are unrelated to the dictatorship. The others are described as playing "an essential role in documenting testimony, denunciation, and experiences in the years of the dictatorship."<sup>32</sup> While this description of the arpilleras acknowledges their role in documenting the counter-narrative of many Chileans, it doesn't go the step further and acknowledge the women and their essential role in the re-democratization process in Chile. Like the marginalized arpilleristas themselves, their works of art are isolated and detached from the public sphere of historical discourse in the museum. The artists are not acknowledged for their importance outside of their identities as struggling working class mothers.

## Conclusion

The association of men with public sphere and women with the private domestic sphere was an ideology that was central to the legitimation of the dictatorship, and discredited the arpilleristas and their ability to create political change. However, due to this oversight, the arpilleristas were able to use a traditionally feminine craft to create a counterpublic for marginalized women, and became involved in politics. The celebration of the artistic expression and resilience of arpilleristas is presented differently between national and international communities. While the international community focuses on emphasizing the women and their marginalized status, eliciting a sympathetic response from the reader, the national Chilean sources acknowledge the arpilleras as important artifacts in

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32. La Fundación de Documentación y Archivo Vicaría De La Solidaridad.

preserving counter-narratives and memories of oppression under Pinochet.

Yet the Chilean resources do not recognize arpilleras as a political tool in public spaces like museums and art exhibits. The common denominator between the international and national sources is the general lack of knowledge and awareness of the arpilleras and their impact on Chilean history. This disparity is reflected in the value of the public sphere and its association with men and politics, contrasted with representations of women and their expected role in the private sphere. But by utilizing their expected gender roles in the private sphere through folk art, the arpilleras were able to document their narratives of the dictatorship, and use their collective memories to rise up against Pinochet's military regime.

Due to the cultural expectation for women to be confined to the domestic sphere, arpilleras provided the context for a grassroots movement that defied the military regime while simultaneously creating a counterpublic in which marginalized women could document and preserve their memories of the dictatorship. By passing on their memories through arpilleras, the arpilleras teach us that even if we have the privilege to forget a violent history, we cannot afford for history to repeat itself. The arpilleras today critique our collective historical memories and remind us that history so often tells the man's story, a story of war and violence, but neglects to commemorate its psychological effects of generational trauma.



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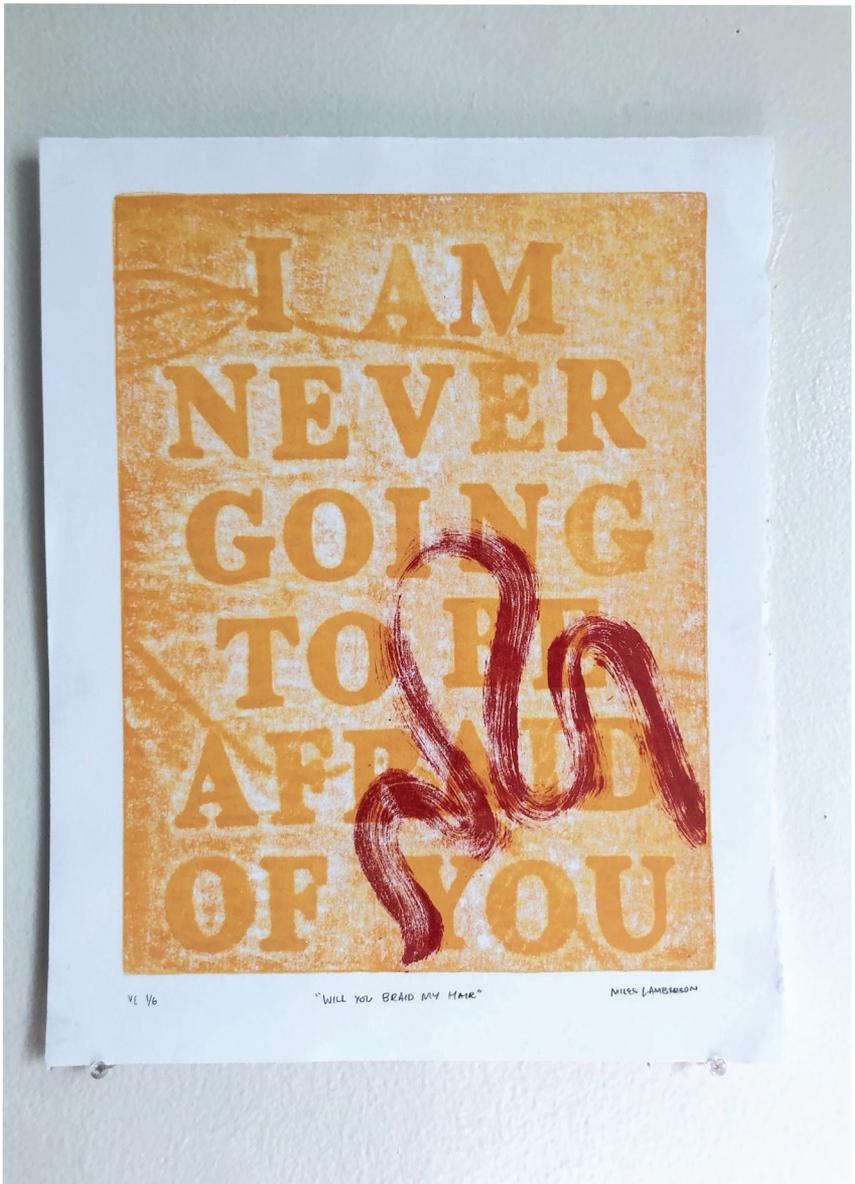
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**"Will You Braid My Hair" by Miles Lamberson**



VE 1/6

"WILL YOU BRAID MY HAIR"

MILES LAMBERSON

# Votes Against Migration: Modeling Legislators' Preferences

**Abstract:** Immigration is a salient issue across the global north, particularly in times of mass migration. From walls and deportations to open borders, our governments have ever-changing solutions to the dynamic web of challenges of human migration. Why can the 27 nation bloc of the European Union accept an open border policy amongst one another but refuse the same policy to refugees from Syria? In short, it often depends on the “kind” of immigrants legislators are concerned with when voting on whether to tighten or loosen their countries’ immigration policy. This paper expands upon an existing model which examines immigrants’ skill level as a primary factor for legislators. Depending on existing welfare and taxation policy, immigrants’ skill profiles compared to the profile of legislators’ districts can be a determining factor for legislators’ voting behaviors on immigration policy. In flat or regressive tax systems, for instance, high skilled workers can be fiscally burdensome on welfare systems like pensions, making them an unattractive immigrant profile. This paper models the point at which the skill profiles of migrants and a legislator’s district would generate a vote in favor of more lenient migration policy.

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Michael currently lives in Amsterdam, pursuing his passions for language, policy, and the environment. He completed his MSc in Political Economy at the University of Amsterdam, focusing on international trade theory and law, and works as an analyst in the European renewable energy market. Beyond work, Michael is studying emissions trading and carbon taxation in the European Union, and hopes to ultimately write environmental policy for the European Commission.

A recent resurgence in rhetoric around immigration has lent itself to the interest of economists and political scientists. As countries have struggled with increasing global displacement and migrant crises, legislators have been fighting over the best ways to address the issue. In the case of the United States, this has included calls for a complete overhaul of our immigration system. Both major parties in the US have had pro and anti immigration voting streaks, so what actually motivates legislators to vote the way they do regarding immigration policy? That is the objective of this paper. Recent economic research has developed theoretical models for how legislators vote based on the types of workers that make up the constituency of legislators' respective districts. This paper seeks to extend that model, incorporating the fiscal benefits of immigrant pay-ins to pension systems like Social Security. The new model will demonstrate when a legislator will vote in favor or against open immigration policy when considering pension contributions of immigrants.

Following the Syrian refugee crisis and other mass exoduses from developing countries facing conflict, persecution, and poverty, there has been a revival in global discussions on how to deal with increasing migration. In particular, movements have sprung up across the United States, Europe, and Israel calling for state suppression of immigration through regional or ethnic bans, border walls, deportations, and decreased visa granting (Alexander, 2019; Riegert, 2019). In countries where such movements have captured political power, such as Poland and Hungary, state sanctions have been imposed. Both examples have refused to accept a single refugee through European Union Syrian refugee relocation efforts (Broomfield, 2016). In the United States, there are currently concerned legislative efforts to erect a wall along the southern border, eliminate family or chain migration, and drastically increase border detentions and deportations (Rampton, 2019). There are, of course, many perceived and real reasons groups and states advocate for stricter or more lenient immigration policies. Workers fear a decrease in

wages and increased employment competition, while some may have reservations regarding cultural values and conflict, crime, isolation, and overall social cohesion.

Top destination countries are currently facing a demographic based labor challenge. As fertility rates have been dropping, population growth has slowed, and in the cases of Japan, Poland, and Hungary, population growth has even entered negative rates (Börsch-Supan, 2003; World Bank, 2019). This has translated into an aging population with lower working aged persons having to contribute to pension systems increasingly burdened by growing retiree populations. The United States and Germany are two examples of countries that have effectively kept their population growth from falling too low. Germany actually reversed its trend of a falling growth rate, which fell into the negatives in 2004 and currently stands at 0.42%. They have been able to achieve this largely by admitting a remarkably vast amount of refugees during the ongoing Syrian refugee crisis and economic migrants from Eastern Europe. The United States has enjoyed a fairly stable population growth rate between 0.7 and 1.2%, with the current rate holding at 0.713%, mainly due to its significant and sustained immigration flow (World Bank, 2019). The global trend of decreasing fertility and its fiscal impacts point to the question of why countries sometimes oppose increasing immigration to their countries by alleviating immigration restrictions.

Legislators' voting behavior is intimately connected with the political persuasions of their constituencies, but that is not the sole determinant of how a legislator may vote. Party behavior, political agreements, and special interests also influence a legislator's voting behavior, even to the point of such behavior deviating from the will of his or her constituency. How, then, can we assess and predict the voting behavior of legislators on immigration? Developing a formal model of legislators' choice to vote for or against the interests of migrants may lend itself to addressing the global crisis of 68.5 million displaced persons worldwide (Edwards, 2018).

The model I have developed through this work builds upon the work of Giovanni Facchini and Max Friedrich Steinhardt in 2011. In their work, the authors use US immigration data from 1970 to 2006 to determine the causes of US House of Representatives legislators' votes on immigration. They particularly focused on legislators' constituencies' makeup within local labor markets, or whether workers in a house district were low or high skilled. Facchini and Steinhardt developed a theoretical model predicting the voting behavior of a hypothetical district's representative per the district's worker makeup. This model was developed under the assumption that legislators are welfarist. This means the model assumes legislators' primary determinant of whether they vote for or against immigration is the impact of immigration on the utilitarian social welfare of their constituents. The model shows that "[a legislator] is more likely to favor an open immigration policy towards unskilled immigrants the more skilled labor abundant is his/her district." When comparing their model to historical data, Facchini and Steinhardt found the data to be consistent with the model's predictions: "representatives from more skilled labor abundant districts are more likely to support an open immigration policy." Their work is suitable for expansion with the inclusion of other possible determining variables to produce a more comprehensive model.

My expansion of the Facchini/Steinhardt model includes not only the skill makeup of a hypothetical house district, but also immigrants' fiscal contribution to pensions. Economist Tito Boeri in the journal *Economica* writes that in most cases, immigrants do provide net positive contributions to countries' welfare systems, though these contributions are smaller than natives' (2010). However, the latter finding is largely due to immigrants' lower economic positions, whereby most immigrants take on low-paying, low-skilled labor compared to natives. Boeri writes that for the European Union, the percent share of taxes and pension contributions paid by migrants over their percent share of the population is an average of 0.57. In some countries, such as Spain,

the number is over 1, meaning migrants are overrepresented in contributions to the country's pension system. Naturally, the variations between countries are largely dependent on institutions and fiscal regulations. Assuming taxed income is greater than received social transfers, Boeri goes on to say that a "large share of migrants to the domestic population allows the spread of the benefit externality over a larger population, including those migrants who are already living in the country." For the United States, the National Immigration Forum estimates the lifetime fiscal benefit of recently arrived immigrants over a 75 year period to be \$259,000, and overall immigrants contributed \$123.7 billion to the Social Security fund, out of the \$786 billion reported by the Social Security Administration (2015; Kosten 2018). This means immigrants contributed 15.7% of Social Security's contributions for the year, while occupying 13.3% of the population. Like in Spain, immigrants in the US are overrepresented in pension contributions, relative to their share of the population.

Accounting for immigrants' contribution to national pension systems in welfare modeling is the goal of this paper. Ultimately, the underlying question is whether such considerations produce different voting behaviors for legislators from considering simply the skill makeup of a legislative district. The Facchini/Steinhardt model is written as:

$$W = \beta_{Li} w(h) + (1 - \beta_{Li}) r(h)$$

$W$  denotes the utility level of the average worker, which serves as the objective function.  $\beta_{Li}$  denotes the ratio of low skilled workers ( $L$ ) in hypothetical district  $i$ , to the district's total population ( $N$ ). This means  $(1 - \beta_{Li})$  denotes the ratio of high skilled workers ( $H$ ) or  $\beta_{Hi}$ . The ratio of high to low skilled workers ( $h = H/L$ ) is  $h$ , with  $w$  expressing the wage rate and  $r$  expressing the equilibrium rate of return to human capital, or salary. With  $\beta_L$  on the x-axis and  $\partial W / \partial h$ , or the marginal utility of the average worker, on the y-axis, Facchini and Steinhardt produced a positive sloping line that intercepts at the critical point,  $1/(1+h)$ . This indicates a positive

and linear relationship between  $\beta_L$  and  $\partial W/\partial h$  in their model.

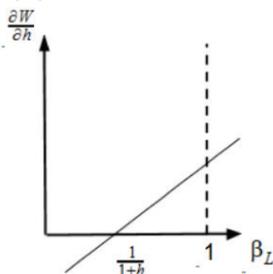
In my extended model, I introduced  $\rho_L W_F$  and  $\rho_H W_F$ , representing the pension payments received by low and high skilled workers, with the assumption that  $\rho_H > \rho_L$ . These are incorporated into the utility variables ( $U$ ) for the respective skill levels.  $\rho$  represents an individual's share of the pension pool, while  $W_F$  represents  $(\beta w(h) + (1-\beta)r(h))$ , which is Facchini and Steinhardt's original utility function without pension considerations. The new model follows the following proposition and function:

*Proposition*

A representative's support for an open immigration policy increases (decreases) when the ratio of low-skilled workers to the total worker population in his/her district is increasing (decreasing).

$$W = (\beta)U_L + (1-\beta)U_H = \beta(w(h) + \rho_L W_F) + (1-\beta)(r(h) + \rho_H W_F)$$

Like in Facchini and Steinhardt's proof, the derivation  $\partial W/\partial h$  in my model produces the same x-intercept. The function produces a downward facing parabola. Because  $\beta_{Li}$  is a ratio and must be  $0 \leq \beta_{Li} \leq 1$  as  $\beta_{Li} = N_{Li}/N$ , with the total population  $N = N_{Hi} + N_{Li}$ , the function is not counted past  $\beta_{Li} = 1$ . As a result, the function produces the following graph:



Like the Facchini-Steinhardt model, my model produces a positive slope, indicating a positive relationship between the makeup of a district by low skilled workers and a legislator's

vote in favor of more lenient immigration policy when pension considerations are added. Once the skill makeup of a district in terms of low skilled workers surpasses  $1/(h+1)$ , known as the critical point, legislators will vote for immigration. This is in line with the Facchini-Steinhardt model where prior to  $1/(h+1)$ , immigration does not increase the welfare of workers for a legislator to favor pro-immigration policy, while past  $1/(h+1)$ , it does. As  $\partial W/\partial h$  or the marginal welfare is a derivative of the welfare function, the most important aspect is whether or not the line representing the function is positive or negative, meaning above or below the x-axis. This tells whether the average worker's welfare is increasing or decreasing, thus determining a legislator's vote preference. The nature of the relationship between the low skill ratio and marginal welfare, however, changes from a linear in the Facchini-Steinhardt model to a quadratic one when adding pension considerations. This is due to an additional multiplication of  $\beta$  with respect to the original model. In the figure above, the plot appears linear due to the large slope of the marginal utility of the average worker. Because of its quadratic nature, the positive slope is diminishing as it moves along the x-axis. This means that though the utility of the average worker increases past the critical point, it does so at a diminishing rate. Interestingly enough, this is only true in a regressive pension tax system where  $\rho_H > \rho_L$ . This is likely due to the increasing tax burden high skill workers pose whereby they receive higher pension transfers than they pay in, relative to their income, compared to low skilled workers. In a progressive pension tax system where  $\rho_H < \rho_L$ , there is no diminishing effect.

This finding begs the question, why do legislators and constituencies in low skill areas throughout the world continue to exhibit intense xenophobia and opposition to immigration despite its potential to increase their welfare? Even in countries such as Poland, where the majority of workers are low skilled and mass immigration would not only increase most workers' welfare but also solve the fiscal burden of an aging population, national rhetoric and legislative behavior has been opposed to

immigration (ILO, 2019; Broomfield, 2016). One significant contributing factor is identity. Economists George A. Akerlof and Rachel E. Kranton focus on the role of identity in economic behavior and preferences. They write that “identity can explain behavior that appears detrimental. People behave in ways that would be considered maladaptive or even self-destructive by those with other identities. The reason for this behavior may be to bolster a sense of self or to salve a diminished self-image” (Akerlof & Kranton, 2000, p.717). This explanation can be particularly appropriate in the context of nationalism and racism. Immigrants, regardless of their benefits, are often seen as threats to sovereignty and social cohesion, in addition to economic well-being for the in-group or native population.

Stephan et al. in the *Journal of Applied Social Psychology* write that there are four categories for individuals’ prejudice against immigrants that, according to Akerlof and Kranton, make constituencies and legislators act against their welfare: realistic threats, symbolic threats, intergroup anxiety, and negative stereotypes (1999). Realistic threats, though often perceived despite the category’s name, include competition for scarce resources, such as territory, wealth, or natural resources. “In the case of symbolic threats, the primary issue concerns group differences in morals, values, norms, standards, beliefs, and attitudes. Symbolic threats are threats to the in-group’s worldview” (Stephan et al., 1999, p. 2222). Intergroup anxiety deals with interactions between individuals from the in-group and members of the out-group. In particular, this notion details feelings of threat to the self as a result of negative outcomes from interaction, including being embarrassed, rejected, or ridiculed. Lastly, Stephan et al. discuss negative stereotypes that are used to justify behaviors and discrimination against out-group members. These threat and stereotype perceptions may lead to attitudes against immigrants that may be stronger than the desire for greater welfare.

Further complicating the matter is the notion of hyperbolic discounting and myopia. People tend not to strategize

well for the future and are short sighted in financial planning and policy considerations. Furthermore, the notion of hyperbolic discounting means we prefer smaller rewards in the short term rather than large rewards in the distant future (Holmes, 2010). Research on this has been particularly popular around retirement planning. In the context of immigration, however, this means the fiscal benefits of immigration are seen as much less important because of their distant reward, while short term challenges are seen as particularly salient.

When adding a consideration of pensions onto the Facchini-Steinhardt model, the relationship between the ratio of low skilled workers to the total population and the marginal utility of the average worker becomes quadratic rather than linear. Facchini and Steinhardt's x-intercept, identical in my model, becomes the first intercept of a downward facing parabola, indicating a positive relationship between the two variables. This strengthens the findings of Facchini and Steinhardt, indicating that as the ratio of low skilled workers rises, so does the welfare of the average worker and so does the likelihood of a welfare maximizing legislator supporting more open immigration policy. A legislator finds the fiscal potential of increased immigration positive for the pension outcomes of his or her constituency, insofar as the amount of low skilled workers surpasses the critical point. However, my model shows that in regressive pension tax systems like in the United States, these benefits are diminishing the more low skilled a district is. Further expansion of the model to include identity based variables may determine the role and effect of social cohesion, desires of homogeneity, and perceived threats or stereotypes in a legislator's consideration of immigration policy.



## **Acknowledgements**

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## Appendix

### *Proposition*

A representative's support for an open immigration policy increases (decreases) when the ratio between low-skilled workers to the total worker population in his/her district increases (decreases).

### *Proof*

Initial model with added pension variables

$$W = (\beta)U_L + (1-\beta)U_H = \beta(w(h) + \rho_L W_F) + (1-\beta)(r(h) + \rho_H W_F)$$

Substitute the equations for  $U_L$  and  $U_H$  and factor according to

variables  $w(h)$ ,  $r(h)$ , and  $W_F$

$$= \beta w(h) + (1-\beta)r(h) + (\rho_L \beta + (1-\beta)\rho_H)W_F$$

Complete the derivative of  $W$  with respect to  $h$ .

$$\frac{\partial W}{\partial h} = \beta[-hf'(h)] + (1-\beta)[f'(h)] + ((\beta)\rho_L + (1-\beta)\rho_H)[f'(h)(1-\beta(h+1))]$$

$$= f''(h)[(1-\beta) + (-h\beta) + (\rho_L(\beta) + \rho_H(1-\beta))(1-\beta(h+1))]$$

Set the derivative,  $\frac{\partial W}{\partial h}$  to be greater than 0 to find the intervals where  $W$  increases

$$\text{If } \frac{\partial W}{\partial h} > 0, \text{ then } f''(h)[(1-\beta) + (-h\beta) + (\rho_L(\beta) + \rho_H(1-\beta))(1-\beta(h+1))] > 0$$

Divide both sides by  $f''(h)$ , sign of inequality flips due to  $f''(h) < 0$

$$(1/f''(h)) * \frac{\partial W}{\partial h} = (1-\beta) - (h\beta) + (\rho_L(\beta) + \rho_H(1-\beta))(1-\beta(h+1)) < 0$$

$$-(1/f''(h)) * \frac{\partial W}{\partial h} = (\beta-1) + h\beta - (\rho_L(\beta) + \rho_H(1-\beta))(1-\beta(h+1)) > 0$$

Solve the equation  $-(1/f''(h)) * \frac{\partial W}{\partial h}$  for a reduced form in terms of  $\beta$

$$-(1/f''(h)) * \frac{\partial W}{\partial h} = \beta^2(h+1)(\rho_L) - \beta^2(h+1)(\rho_H) + \beta(\rho_H)(h+1)$$

$$+ \beta(h+1) + \beta(\rho_H - \rho_L) - (\rho_H + 1) > 0$$

$$= \beta^2 [(h+1)(\rho_L - \rho_H)] + \beta[(h+1)(\rho_H + 1)(\rho_H - \rho_L)] - (\rho_H + 1) > 0$$

The final equation for  $\frac{\partial W}{\partial h}$

$$\frac{\partial W}{\partial h} = -f''(h) * [\beta^2 [(h+1)(\rho_L - \rho_H)] + \beta[(h+1)(\rho_H + 1)(\rho_H - \rho_L)] - (\rho_H + 1)]$$

To solve for the roots of  $\beta$  substitute dummy variables to simplify calculations

$$d = (h+1); e = (\rho_L - \rho_H); f = (\rho_H + 1)$$

Place the new variables into the previous equation for

$$- (1/f'(h)) * \partial W / \partial h$$

$$- (1/f'(h)) * \partial W / \partial h = \beta^2 [de] + \beta [df - e] - f > 0$$

Solve for  $\beta$  using the quadratic formula

$$\beta = (-b \pm \sqrt{b^2 - 4ac}) / 2a = (e - df \pm \sqrt{(df + e)^2}) / 2de = (e - df \pm (df + e)) / 2de$$

Solutions obtained for  $\beta$

$$\beta_+ = 1/d; \beta_- = -f/e$$

Replacing dummy variables in solutions obtained for  $\beta$

$$\beta_+ = 1/(h+1); \beta_- = -(\rho_H + 1) / (\rho_L - \rho_H)$$

Then take the derivative of  $\partial W / \partial h$  with respect to  $\beta$  to verify that

$\partial W / \partial h$  is parabolic function with respect to  $\beta$

$$\partial W / \partial h \partial \beta = -f'(h) [2\beta(h+1)(\rho_L - \rho_H) + (h+1)(\rho_H + 1) + (\rho_H - \rho_L)]$$

Rewriting the equation for  $\partial W / \partial h \partial \beta$  to maintain initial variable forms

$$\partial W / \partial h \partial \beta = -f'(h) [(\rho_H - \rho_L) + (h+1)(\rho_H + 1) - 2\beta(h+1)(\rho_H - \rho_L)]$$

**"I Build the Air" by Emily Chebli**



3/4

"I build the air"

Emily Chebli 2021

# Effects of Sublethal Imidacloprid on House Cricket (*Acheta domestica*) Neuron Firing Activity and Chirping Behavior

**Abstract:** As the human population has grown, so has the use of pesticides to enhance crop yield. Imidacloprid, a pesticide in the class of insect neurotoxins known as neonicotinoids, is the prevailing pesticide for treating common crop pests such as aphids and whiteflies. Lethal doses of the toxin can result in apparent intoxication, tremors, paralysis, and death of an insect, but sublethal doses have been shown to have unusual and unintended effects on non-target organisms such as crickets. Due to the observed partial paralyzing effects of the neonicotinoid, it was hypothesized that sublethal doses of imidacloprid could affect important aspects of a male cricket's chirping behavior, a characteristic vital for the reproductive success of the species. In this study, sublethal doses of imidacloprid were administered to crickets to investigate potential effects on chirp quality, including changes in interpulse intervals which affect a female's recognition of the mating call. Changes in neuron firing activity were also directly observed to assess the extent to which neuronal activity was being impaired by the neurotoxin. Results indicate no significant effect on chirping behavior and a significant effect on neuronal activity with imidacloprid intoxication, which suggests that a female cricket would likely be able to recognize the mating call of males exposed to imidacloprid. However, other aspects of sensation and behavior may be impaired for these animals.

## Jenna Joyner



Jenna graduated in 2019 from Warren Wilson with honors in biology. Jenna explored her passion for genetics in the Genetics Lab under Alisa Hove, and her passion for neuroscience through an internship with Hinds Feet Farm. Jenna presented her thesis at the Association of Southeastern Biologists and the Symposium for Young Neuroscientists and Professors of the SouthEast. Jenna is currently working as the Chemistry Lab Manager and Chem Crew supervisor at WWC and aspires to pursue a masters degree in genetic counseling.

## Introduction

Imidacloprid was the first neonicotinoid to be commercialized in 1991 and is the most widely used pesticide for treating common crop pests such as aphids, termites, and whiteflies (Jeschke et al., 2011; Benzidane et al., 2017). Pesticides can be beneficial for farmers because, with the reduction of crop-eating pests, farmers can increase crop yields. Unfortunately, these benefits come with a major problem: the unavoidable transfer of pesticides to surrounding areas where they may have adverse effects on non-target organisms.

Much research has been done on the method by which lethal doses of imidacloprid paralyze and kill insects through the blocking of neuronal nicotinic acetylcholine receptors (nAChRs) within the insect's nervous system. The neonicotinoid binds at the  $\alpha$ -subunits of the postsynaptic nicotinic acetylcholine receptor, preventing the receipt of signals from the presynaptic receptor. This forces ion channels to remain open and prevents repolarization of the neuron (Déglise et al., 2002). This binding site is the same one affected by the alkaloid nicotine, and once binding of imidacloprid occurs, the effect is irreversible. The intake of lethal doses of imidacloprid either orally or topically can result in apparent intoxication, tremors, paralysis, and death of the insect (Costa et al., 2015); however, sublethal doses have been shown to have other, unintended effects on non-target organisms.

Several studies have addressed these impacts, including a study which found that the insecticide affected honey bees' ability to navigate and return to their hive (Fischer et al., 2014). More recently, Benzidane et al. (2017) discovered that sublethal imidacloprid decreased the function of nAChRs in cockroaches, an example of a non-target species. This pesticide has also been found to affect fruit fly memory formation and retrieval (Chen et al., 2012). These kinds of effects may be more common in non-target organisms because of the less-concentrated imidacloprid that may disperse into and persist in the wild. Flores-Céspedes et al., (2012) showed that imidacloprid, while designed to degrade

through aqueous photolysis, can remain present in waterways where light exposure is inadequate, such as in streams or rivers with ample tree cover. A study by Hladik et al. (2018) on the presence of neonicotinoids in major tributaries to the Great Lakes, USA, found imidacloprid at 53% of locations, making it the most prevalent of neonicotinoids examined.

Unintended effects on non-target organisms may affect multiple trophic levels within an ecological system, and crickets are an excellent example of a low trophic level animal that is likely to be introduced to imidacloprid in agricultural and urban environments (Uhl, 2015). While sublethal imidacloprid has been shown to have effects on cricket mass gain, behavior, herbivory, and survival of predation (Uhl et al., 2015), little is known about the effects of sublethal doses on neuron-firing activity or how it affects chirping behavior in crickets. Male crickets produce their signature mating chirp by rubbing their forewings together (Jacob and Hedwig, 2016). This auditory signaling is a crucial element for mating success; if impaired, it could be detrimental to both the cricket population and the ecological hierarchy as these crickets may not be able to find mates and reproduce (Jacob and Hedwig, 2016). Imidacloprid is known to impair nerve impulses in insects; while this has the potential to affect the mating chirp of crickets by partially paralyzing the creatures (Kostromytska et al., 2011), we should be able to directly observe this effect through monitoring changes in neuron firing activity (Kimura-Kuroda et al., 2012). Combined observations of neuron-firing activity and cricket chirping quality following imidacloprid exposure may help reveal whether chirping is being impaired and the underlying mechanism of nAChR impairment.

The goal of this study is to test the effects of sublethal doses of imidacloprid on the common house cricket (*Acheta domestica*) neuron-firing activity and chirping behavior. A lethal dose range for crickets was determined for these animals in a pilot study. Populations of cricket were given topically applied sublethal doses of imidacloprid and observed for neuron firing activity and chirping behavior in different groups.

## Methods

*Cricket preparation*— Crickets were purchased from Petco and kept in a 37x22x25 cm terrarium with perforations on the lid to allow for air circulation. White cotton cloth saturated with a roughly 30% sugar water solution were provided as a food and water source (Benzidane et al., 2017). Scraps of cardboard were included to prevent overcrowding by allowing the crickets to climb and explore off the terrarium floor.

*Lethal Dose Determination*— In order to assure the amount of imidacloprid applied to the crickets was sublethal, a lethal dose study was conducted. Administration procedures were derived from Costa et al. (2015) and Kaakeh et al. (1997). One hundred crickets were separated into ten groups, each receiving a different concentration of imidacloprid. A stock solution of 1000 ng/ $\mu$ L of imidacloprid/acetone was diluted with acetone through serial dilution. Pure acetone was used as a control. Crickets were placed into a 37x22x25 cm terrarium containing two cotton balls saturated in a roughly 30% sugar water solution. Each cricket received 1  $\mu$ L of a previously listed solution concentration on the dorsal side of the thorax, between the pronotum and forewing. Following administration, crickets were observed for fatalities at 24, 48, and 72 hours.

*Neuronal Activity Recording*— Neuron firing activity was recorded from the terminal abdominal ganglion (TAG) on the abdominal nerve cord (ANC) using methods derived from Dagda et al. (2013). The TAG directly connects to organs on the back of the cricket's body called cerci (singular cercus), which are used for the detection of minute air currents (Yono and Aonuma, 2008). Acetylcholine is a vital neurotransmitter in the TAG, so stimulation of the cerci can be used to detect changes in the functionality of neurons containing the nicotinic acetylcholine receptor (Yono and Aonuma, 2008). Fifteen male crickets were separated into three groups of five. 1  $\mu$ L of a high dose (10 ng/ $\mu$ L) or a low dose (0.25 ng/ $\mu$ L) of imidacloprid/acetone solution were applied to each cricket in the same manner used in the lethal dose study, and pure acetone was used as a control. Neuronal

recordings were conducted within 1 hour of imidacloprid administration. Before recording, each cricket was placed in a petri dish and stored in a freezer for 3-5 minutes or until visibly anesthetized to prevent interference from motor neuron activity. Data was collected using a neuron SpikerBox (Marzullo and Gage, 2012), an amplifier that detects the electrical activity of neurons. Anesthetized crickets were placed dorsal side down on a cork bed on the SpikerBox. One electrode pin was inserted in the central region of the thorax, and a second pin was inserted at the base of the abdominal area, near the cerci and into the cork, holding the animal in place. After 1 minute to allow the cricket to warm up slightly but not fully reanimate, recording began. Every 5 seconds, 10 mL of air was puffed over the cerci for 30 seconds, for a total of 6 stimulus events. Once collected, spike count and interspike intervals were calculated using the computer software BYB Spike Recorder (Backyard Brains, 2017).

*Chirp Recording*— Cricket chirping was recorded for 8 hours overnight between the hours of 11pm-9am. Crickets were separated into groups of ten, containing five males and five females. Between 10-12 hours prior to recording, 1  $\mu$ L of 10 or .25 ng/ $\mu$ L imidacloprid/acetone solution was applied to the back of the thorax of each cricket. Pure acetone was used as a control. Groups of crickets were recorded separately in a 2.29 cubic meter sound booth using an Audio Technica AT4040 microphone fitted with a Pop Filter. Audio files were saved in .wav file format. No lights were used in the booth overnight to simulate night time. A HOBO Pendant<sup>®</sup> Temperature Data Logger was placed in the room to record variations in temperature through the night, as previous research has indicated that changes in temperature can impact the pulse rate of crickets (Walker 1962). From each night recording, three one minute sections of constant chirping were selected from the beginning, middle, and end of the night, similar to methods used by Hennig and Weber (1997). For each section, the number of pulses per chirp and the pulse period (inter-chirp period) were analyzed using Logger Pro<sup>®</sup> software.

## Results and Discussion

*Lethal Dose Determination Results*— Concentrations of imidacloprid used for each testing group were based on previous research of lethal doses found for bees and cockroaches, which were 2.41 ng/μL and approximately 2,500 ng/μL, respectively (Kaakeh et al., 1997; Costa et al., 2015). In this study, a stock solution of 1,000 ng/μL was used as the maximum concentration in addition to the following concentrations: 100, 50, 10, 4, 1, .25, and .01 ng/μL of imidacloprid in acetone. After the imidacloprid solutions were applied, crickets were monitored for mortality every 24 hours for three days. Each dosage group contained ten crickets.

None of the concentrations of imidacloprid were able to produce a 100% mortality within 24 hours, so an LD50 could not be calculated (Ahmed, 2015). However, as expected, a general trend of increased mortality with increasing dosage and time was observed, as seen in Table 1 and Figure 1 pictured below. This trend is in line with previous research of LD50 showing similar trends of mortality with respect to dosage and time (Costa et al., 2015).

Dosage	24 hours	48 hours	72 hours
Control	1	1	2
.01 ng/μL	0	2	4
.05 ng/μL	0	2	4
.25 ng/μL	0	1	1
1 ng/μL	0	1	4
4 ng/μL	1	4	5
10 ng/μL	2	5	8
50 ng/μL	3	4	6
100 ng/μL	3	6	7
1000 ng/μL	5	5	6

Table 1. Number of deceased *Acheta domesticus* individuals observed every 24 hours for three days after various concentrations of imidacloprid in acetone were applied. Each dosage group contained 10 crickets.

## % Mortality after 24, 48, and 72 hours

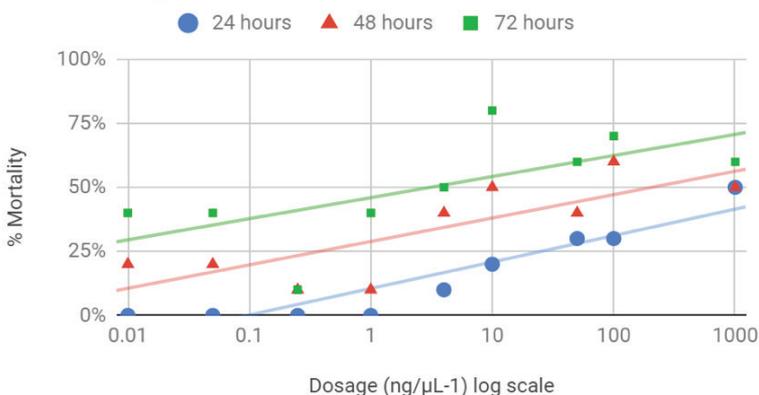


Figure 1. Scatter plot depicting observed mortality of *Acheta domesticus* after 24, 48, and 72 hours. The y-axis indicates % mortality. The x-axis, shown on a log scale, indicates the dosage of imidacloprid given to the individuals in each group. Trendlines indicate an overall trend on a log scale for each day of monitoring.

Visual disruption of motor functions was observed in some individuals after concentrations of 50 ng/μL or more was applied. Immediately after administration of the toxin, these crickets showed rapid twitching and spastic behavior in the limbs, which lasted for several seconds before slowly subsiding after several minutes. After several hours, minor behavioral changes such as mild twitching and abnormal walking patterns were still observed in a few individuals. Crickets would frequently experience difficulty orienting themselves and would walk in circles for periods of time after administration, a sign that they were having trouble controlling the limbs on one side of their body. When flipped onto their dorsal side, these crickets also showed great difficulty in correcting their orientation onto their legs as compared to individuals given lower dosages. These tendencies were not seen in all individuals dosed with concentrations of imidacloprid greater than 50 ng/μL, so variation in susceptibility between individuals may be

noted. Due to the fact that immediate physical effects were not observed in the 10 ng/ $\mu$ L group but were seen in the 50 ng/ $\mu$ L group, the 10 ng/ $\mu$ L concentration of imidacloprid was chosen as the high dose for the following studies. The low dose used for the following studies was determined to be .25 ng/ $\mu$ L because this concentration showed no effect on mortality after 72 hours.

*Lethal Dose Determination Discussion*— In this study, a lethal range of topically applied imidacloprid concentrations were determined for *Acheta domesticus*. Sensitivity to imidacloprid intoxication appears to be relatively low for this species as compared to other similar animals. For example, when imidacloprid is applied in the same manner used here, the LD50 after 24 hours for the bee species *Melipona scutellaris* Latreille is 2.41 ng/ $\mu$ L (Costa et al., 2015). While higher doses of imidacloprid did result in a higher mortality rate, even the highest dose of 1,000 ng/ $\mu$ L, the stock solution, did not result in 100% mortality. This indicates that crickets are relatively robust to topical application of imidacloprid, however, it should be noted that the method of intake is likely a contributing factor to this high intoxication resistance. In other studies, insect species such as *Apis mellifera* have demonstrated be much more susceptible to imidacloprid poisoning when the toxin is ingested, rather than topically applied (Suchail et al., 2000). Therefore, it is likely that if imidacloprid was administered orally, the crickets would have shown a higher mortality rate with lower concentrations. Ingestion is more often the case of intoxication for herbarious animals (Wood and Goulson, 2017); however, this method was not used in this study because the observation of a general intoxication response was intended.

The concentrations of imidacloprid used in the neuronal and chirping response studies were determined as a result of this lethal dose study. These concentrations of .25 ng/ $\mu$ L and 10 ng/ $\mu$ L are not abnormally high for areas in which imidacloprid or other neonicotinoids are regularly used (Sur et al., 2003). Often, the method by which neonicotinoids are applied in agriculture is by seed dressing, in which seeds of the target crop are coated

with the insecticide to allow it to be absorbed by the plant as it grows (Dang et al., 2011). Unfortunately, this process only results in 1.6-20% of the active ingredient being absorbed into the plant (Sur et al., 2003). The remaining chemicals bind to soil particles which can reach concentrations of 0.09–10.7 ng/g of imidacloprid in soil found around the edge of agricultural land in which seeds are planted (Wood and Goulson, 2017). When this soil comes in contact with water, the insecticide can be released into waterways and accumulate (Bonmatin et al., 2015). As mentioned above, ingestion of the toxin often results in behavioral and physical effects at lower concentrations than when applied topically, so it is not unlikely that a cricket could come in contact with and/or consume a high dose of 10 ng of imidacloprid in these types of environments.

*Neuronal Activity Results*—The region of the cricket's central nervous system in which neuronal activity was recorded for this study was the terminal abdominal ganglion (TAG). Male crickets were topically administered imidacloprid in acetone at concentrations of 10, .25, and 0 ng/ $\mu$ L as high, low, and control doses, respectively. Crickets were anesthetized in a freezer before recording to avoid interference from motor neuron activity. Electrode pins from an electrical amplifier were inserted into the body of each cricket and a puff of air was used as a stimulus during recording. Results from a spike count analysis indicated that the high dose group was significantly different than the other two groups, and that overall change in activity with imidacloprid was significant ( $p < 0.001$ ).

Neuronal recordings were analyzed using a standard spike count procedure. For each recording, a threshold which encompassed only spikes within stimulus regions were established for both the positive and negative voltage areas. Spike points within these regions were counted and then averaged between the top and bottom thresholds. The outcome of this count was assessed and individuals outside of one standard deviation of the mean were eliminated from analyses. Results of this assessment are pictured below in Figure 2. A one-way

analysis of variance (ANOVA) was performed resulting in a p-value less than 0.001 and a high F-value ( $F_{2,14}=20.936$ ), indicating that the null hypothesis was not supported. Following this, a post-hoc test was performed which indicated that this high F value was the result of the significant differences observed between both the control and low dose groups and the high dose group ( $p < .001$  and  $p = .001$ , respectively), rather than the control and the low dose group, which was not significantly different ( $p = .583$ ).

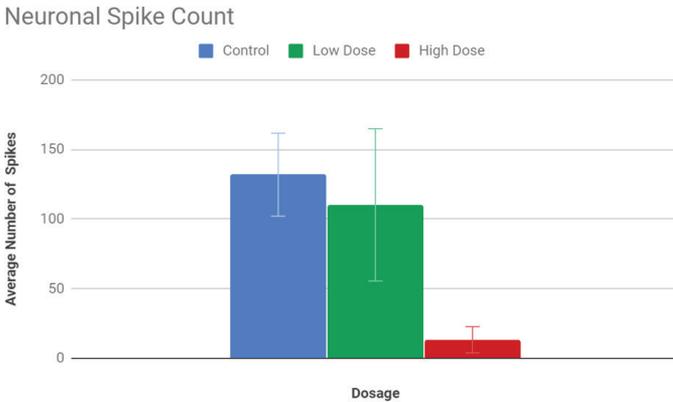


Figure 2. Bar graph indicating the average number of spikes calculated from each neuronal recording of *Acheta domestica* one hour following application of imidacloprid solutions. The y-axis indicates the average number of spikes and the x-axis shows each dosage group. Error bars indicate the standard deviation between individuals.

*Neuronal Activity Discussion*— In this study, impairment of neurons in the terminal abdominal ganglion were observed through the measurement of electrical impulses resulting from neuron firing activity within the nervous system of *Acheta domestica*. Results from neuronal recordings indicated significant effects imidacloprid on neuron firing activity within the TAG. The recordings showed a decreasing response to the stimulus with increasing dosages of imidacloprid. This may seem counterintuitive that a stimulant such as imidacloprid would

result in reduced neuron firing activity, rather than an increased response, however, this result is likely due to the permanent binding of imidacloprid to the nicotinic acetylcholine receptor. During initial binding, imidacloprid causes ion channels to remain open, prompting the cell to constantly fire (Casida and Durkin, 2013; Rondeau et al., 2014). Over time, however, because the cell is unable to rebalance its electrochemical gradient, it loses its ability to fire and becomes functionally dead. This is likely why a reduction in activity was observed rather than an increase. An example of this can be seen in a study by Dagda et al. (2013) in which nicotine injected into the cricket's central nervous system during neuron firing recording induced a dramatic increase in activity resulting in a peak count of 2538 over five seconds as compared to a peak count of 13 for the control. Nicotine and imidacloprid bind to and stimulate nAChRs similarly, so if observation of imidacloprid intoxication occurred directly following application of imidacloprid instead of an hour after, an increase in overall activity would have likely been observed.

Neuronal recordings indicated that the crickets had reduced neuronal response to stimulation of the cerci (singular cercus), a sensory organ vital for detecting and avoiding predation. This reduced activity likely resulted in reduced sensation and perception of a stimulus, an impairment which would affect the animal's behavior and longevity. Research by Kanou et al. (2002) found that when they ablated the cercus of the cricket species *Gryllus bimaculatus*, the animals showed reduced escape behavioral response to an air stimulus. In the wild, this reduced response could increase the likelihood that the cricket would not be able to detect a predator as effectively and impair its evasive capability. The observed impairment in muscle movement which persisted hours after the insecticide was administered could contribute to increased predation as the animal may experience increased difficulty escaping the predator. If predation is increased for individuals who have been exposed to imidacloprid, it could have a disproportionate strain on the cricket population and result in a higher intake of imidacloprid

in the predator species. Fortunately, there has been no evidence of the bioaccumulation of imidacloprid in predator species (Pisa et al., 2017); however, the toxin has been shown to be harmful to insectivorous animals such as birds. In a case study conducted by Hallmann et al. (2014), dramatic declines in the insectivorous bird species of passerines found on farm lands which used neonicotinoids, including imidacloprid.

*Chirp Recording Results*—Recording of chirping occurred 8-10 hours after imidacloprid was applied to male crickets. Chirping was recorded overnight in a soundproof recording booth for 8-15 hours. Sections of isolated chirping were selected from these recordings and these selections were used in the analysis. An example of one of these selections can be seen below in Figure 3. Potential changes in interchirp, interpulse, and pitch were assessed through the analysis of Fourier transforms made for each recording group. Results indicated no significant difference in interchirp, interpulse, or pitch between recording nights, and no trend of difference was observed.

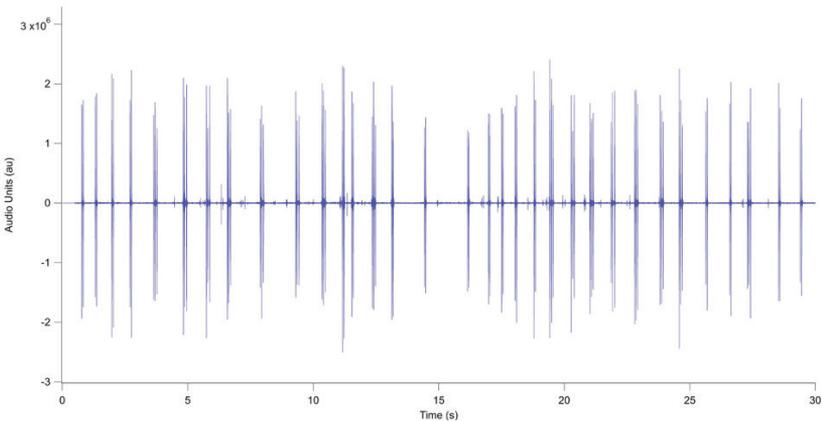


Figure 3. Oscillogram showing audio units (au) over time (s) of a 30-second section of chirping recorded from a group of control *Acheta domesticus*. Each spike in activity over one or under negative one audio units illustrates a chirp.

Isolated sections of chirping were integrated into one recording for each night. A Fourier transform was performed for

each night of recording in order to identify potential changes in interchirp, interpulse, and pitch between dosage groups. Graphs of each Fourier transform were visually inspected for peaks which correspond to interchirp, interpulse, and pitch. These peaks were identified by assessing reasonable peak range which would be expected for sounds produced by biological animals rather than electrical or mechanical interference which would produce sharp peaks with little to no range of frequency. The frequency location of the maximum point of each peak was recorded, as well as the midpoint range. Results from this peak identification can be seen in Figures 5-7. Interchirp or interpulse results show very little variation between all recording nights with no trend of variation. The same is true for variation in pitch frequencies, with the exception of one of the high dose nights, which showed a pitch frequency of  $\sim 8,200$  Hz, dramatically higher than the pitch frequencies of all other nights which ranged from  $\sim 4,500$ - $5,200$  Hz. No statistical analyses were performed because there were only two replicates for each dosage group.

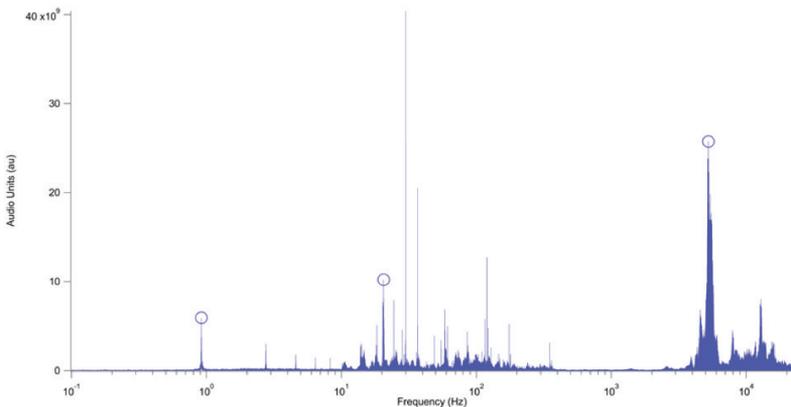
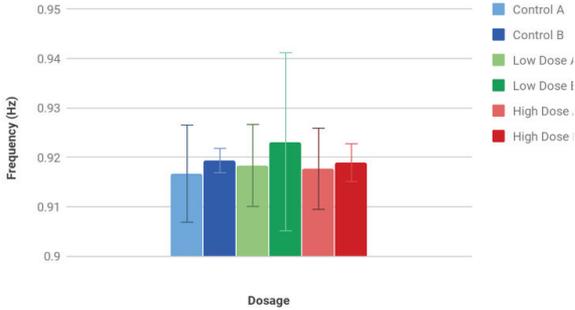
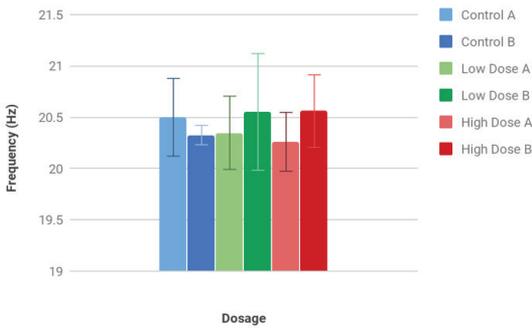


Figure 4. Example Fourier transform for one recording night of a control group of *Acheta domestica*. The y-axis indicates audio units, and the x-axis displays frequency on a log scale. Peaks corresponding to interpulse, interchirp, and pitch are indicated from left to right respectively. Height of the peak indicates frequency prevalence during the recording. Peaks illustrated without frequency range indicate that they are not biological in nature and are likely the result of electronic interference.

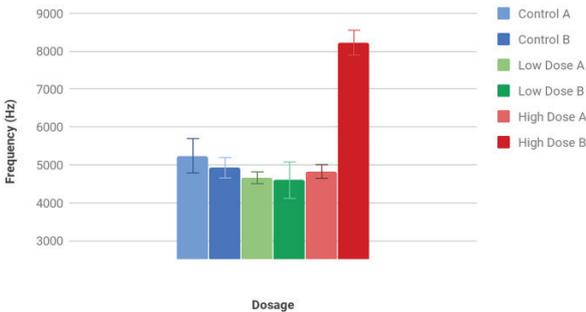
Interchirp Variation Between Recording Nights



Interpulse Variation Between Recording Nights



Pitch Variation Between Recording Nights



Figures 5-7. Bar graph depicting interchirp, interpulse, and pitch frequency variation between recordings of *Acheta domesticus* given topically applied concentrations of 10, .25, and 0 ng/ $\mu$ L of imidacloprid in acetone. The y-axis shows frequency in Hz and the x-axis is the dosage. Error bars indicate the midpoint frequency range for the peak. Blue bars represent the two control group night recordings, green represents the low dose groups, and red is the high

dose.

Of the six recording nights, temperature data was only collected for four nights due to user error with the HOBO Pendant® Temperature Data Logger. Of the four nights in which data was collected, the maximum standard deviation of temperature within a night was .39 C, and standard deviation between all nights was .81 C. Research by Walker (1962) has indicated that the species *Gryllus rubens*, a cricket within the same family as *Acheta domesticus*, will not alter the pulse rate of its chirps with temperature variations below 4.8 C. Due to the meniscal changes in temperature observed, no statistical accommodations for temperature variations between nights were performed.

*Chirp Recording Discussion*— Imidacloprid, while appearing to affect muscle movement in the limbs of the animal, was not observed to affect the crickets ability or willingness to chirp, or quality of chirping in any of the aspects measured. The results from the Fourier transform indicated that, regardless of the dosage of imidacloprid given, interchirp, interpulse, and pitch remained relatively the same, with the exception of one high dose recording which showed a pitch increase of nearly 3,000 Hz. This anomaly cannot be easily explained after consulting previous literature; however, because this night showed normal interchirp and interpulse frequencies, and no trend of pitch variation occurred in the other recording nights, this abnormality is likely not due to imidacloprid intoxication. Disregarding this anomaly, because the interchirp and interpulse remained relatively constant in the other recording groups, it is probable that a female would still be able to recognize these calls as coming from a member of her own species and respond accordingly.

While a female would likely be able to recognize these calls as coming from her species, it is possible that she may show a preference between them based on other characteristics of the sound. Research done by Hedrick and Weber (1998) found that females of the species *Gryllus integer* showed a preference for males who exhibited longer chirp periods with fewer and

shorter pauses in chirping. Another study, performed on *Acheta domesticus*, demonstrated that females have a preference for chirps emanating from larger males which contain more pulses per chirp (Gray, 1997). These parameters of extended time between chirps and number of pulses within a chirp were not investigated in the present study; however, investigations of these aspects may be of particular interest in future studies on female response.

## General Discussion

In this study, chirping behavior and neuron firing within the TAG was observed following imidacloprid intoxication at varying concentrations. Though neuron firing within the TAG was revealed to be significantly affected by high levels of imidacloprid intoxication, chirping behavior was not significantly affected. Investigations of the locations on abdominal nerve cord (ANC) within crickets that are responsible for different aspects of chirping have been performed by Jacob and Hedwig (2016). Through the lesioning of different ganglia along the ANC, they found that when the TAG and the ganglion immediately above it (A6) were disconnected from the nervous system, the crickets were still able to produce a normal chirp. However, when any other ganglion within the abdominal chain was cut, a change in chirping occurred. When connections to the ganglia A5 and A4 were severed, changes to the interchip were observed, and when ganglia A3 and A4 were severed, changes to the interpulse were observed (Jacob and Hedwig, 2016). It is likely these ganglia were not being affected by the toxin because these aspects of chirping were not affected by imidacloprid in the present study.

Imidacloprid did not affect the male's ability to chirp or quality of chirping such that a female would not be able to recognise the call as coming from her species, however, investigation into the effects of imidacloprid applied to the female may impact her ability to recognise and respond to the call. Stout and Huber (1972) determined in their work on *Gryllus campestris* L. that the location of auditory neurons which respond to chirps

as well as individual pulses are within the head ganglia of the animal. Nicotinic acetylcholine receptors can be found within the head ganglia of insects (Tomizawa and Casida 2001), so binding of imidacloprid may occur here and alter the female's ability to recognize the male's mating call.

Investigation of the effects of neonicotinoids on non-target organisms is vital in the assessment of the regulation of their use. The vast majority of the research of neonicotinoids on non-target land animals have been on honeybees, and results of these studies have been used in support of regulation and prohibition of neonicotinoids (Yang et al., 2008; Fischer et al., 2014). The European Union, for example, has banned three neonicotinoids, including imidacloprid, from all outdoor use, and it seems the sentiment is gaining popularity around the world (Rondeau et al., 2014). As imidacloprid and other neonicotinoids continue to exhibit harmful effects on non-target organisms in both experimental and environmental conditions, legislation which bans or strictly regulates their usage may become more widespread.



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**“Organic  
Vectors”  
by Katherine  
Wilson**

# Testing Temper: A Functional & Cultural Analysis of Soapstone Temper in Burke Series Pottery

## Abstract

The study of the production of archaeological ceramics can shed light on the lives of individual potters, the broader culture of those potters, and the interactions between individuals and culture. The choice of how to make a pot (materials, techniques, shapes, sizes, decorations, designs) is made by an individual potter (or group of potters) but is also constrained and enabled by larger social structures. This study examines the choice of soapstone as temper in Burke series ceramics of Western North Carolina. This study approaches the selection of temper in both a material science-based experimental analysis and with consideration of the cultural context of the choice. In the experimental analysis, soapstone-tempered ceramic tiles were tested for strength and compared to tiles that had undergone repeated thermal shock to test for thermal shock resistance. Soapstone temper resulted in a loss of strength and no significant advantage in thermal shock resistance. Therefore, the selection of soapstone temper in Burke ceramics is more likely explained by cultural rather than functional factors.

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## Introduction

### *The past, material culture, choice, and technology*

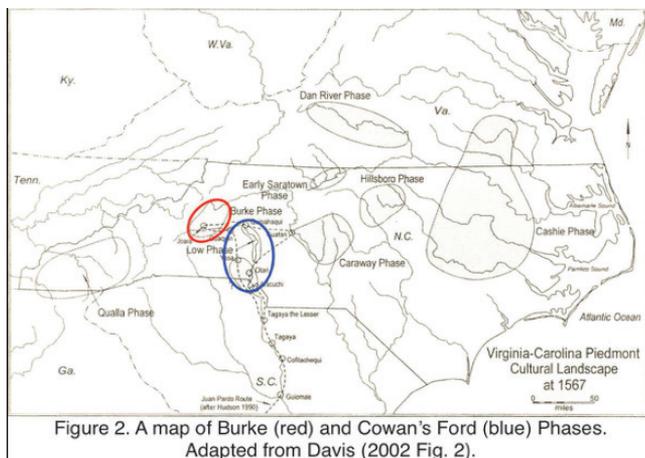
Every choice that a person makes, either as an individual or as a member of a community, has meaning. Anthropologists analyze a group's daily choices and activities to better understand the worldviews and lifestyles of that group. Archaeologists, a subset of anthropologists, study materials that have been modified by people in order to gain insights into the behaviors of those peoples. Archaeologists often examine choices made by past peoples. Even the smallest variation—i.e. the result of a choice—in the archaeological record can represent a change or difference in many characteristics, including cultural adaptation or identity. Evaluating a choice as small as the specific type of temper (a foreign material added to clay before it is fired) can provide an archaeologist with important insights into the pottery production process and related activities of past peoples. In this study, I examined the Burke potter's choice to use soapstone as a temper in their pots and what it might reveal about the Catawba Valley Mississippian people of the Burke phase. Through experimental methods, I tested whether this choice had clear, practical advantages. Are soapstone-tempered ceramics stronger or better suited to thermal shock compared to sand-tempered or untempered ceramics?

Figure 1. A Burke Inscribed Ceramic Bowl.



## *The Burke Phase*

The Burke phase is a term used by archaeologists to refer to a group of people living in the western North Carolina Piedmont from 1400-1600 C.E. (Beck and Moore 2002; Rodning et al. 2011). The phase is defined as a “regionally and temporally distinct distribution of earthen mounds and soapstone-tempered ceramics along the upper Catawba and Yadkin rivers” (Beck and Moore 2002:192). Archaeologists categorize peoples into geographical and temporal phases “characterized by either the presence-absence or differential frequencies of various cultural characteristics” (Plog and Hantman 1990:440) of their material culture. Recognizing phases is important to help establish cultural chronologies and to identify regional cultural change. The Burke phase occurs within the geographically larger Mississippian culture (800-1600 C.E.) that encompasses many different cultures of and is defined by increasing social complexity, mound building, maize agriculture, and shared iconography.

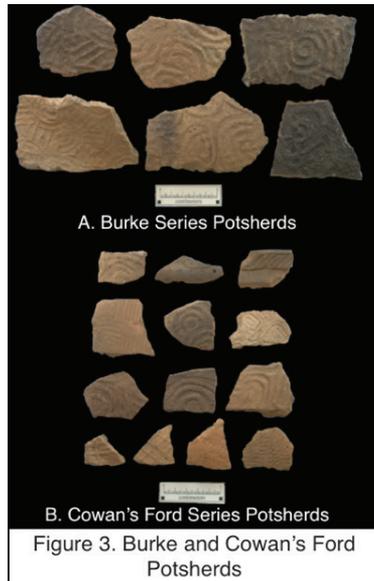


Some of the present-day descendants of the peoples of the Burke phase include the Catawba Nation, located in Rock Hill, South Carolina. Catawba potters continued the production of sand-tempered Cowan's Ford series ceramics through the early colonial period until 1759, when a devastating smallpox

epidemic killed half of the Catawba population, which prompted a coalescence of the Catawba population and the production of a new style of ceramics designed for the new Euro-American and African-American markets in the British colonies (Blummer 2004, Riggs 2010, The Catawba Nation 2012). The production of soapstone-tempered Burke series ceramics appears to have stopped sometime before the English colonial period, as there is no archaeological evidence of soapstone-tempered pottery in colonial-period Catawba sites, even prior to 1759. The ancestors of the Catawba/Burke were recorded as “Yssa” by the Spanish in 1567 and “Esaw” by the early English colonists (Riggs 2010) but the Catawba River regions “featured a large population for at least two hundred years prior to European contact” (Beck and Moore 2002: 192). Archaeology has often functioned as a colonial discipline that has framed indigenous peoples as solely part of the past which contributes to the dispossession of both their identity and even their land. Although the use of soapstone temper is no longer used by modern Catawba potters, Catawba pottery is extremely important as one of the rare ceramic traditions of the eastern United States to survive colonialism and is still practiced today (Blumer 2004) The Catawba Nation (2012) considers pottery to be a cornerstone of their culture and had programs dedicated to keeping the tradition of Catawba pottery alive.

Robert Keeler (1971) was the first archaeologist to describe Burke series ceramics, which were further defined by David Moore (2002). Burke series pottery is tempered with crushed soapstone and consists mainly of jars with complicated stamped or plain surface treatments and carinated bowls with incised or burnished surface treatments (Beck and Moore 2002:196). Moore (2002) identified Burke series pottery as a variant of Lamar pottery, a style of ceramics that was widely spread across the Southeast (Williams and Shapiro 1990; Riggs 2010:32-33). Within the Catawba River valley, sand-tempered Cowan’s Ford series also occurred during the Burke phase. It is found on the lower Catawba River, south of the distribution of the Burke series pottery, and shares vessel forms and exterior

surface decoration patterns with the Burke series (Moore 2002:265).



### *What is temper?*

Archaeologists generally define temper as non-plastic inclusions added to the clay by potters for a variety of reasons but most often to reduce cracking during drying and firing (Shepard 1957; Alberto Santacreu 2014). There are debates in ceramic archaeology about the precise definition of temper and what should count as temper. For instance, should mica found naturally in clay be considered temper? (For a more detailed overview of these questions see Rice 1987:408-413.) For the purposes of this paper, I consider the Burke phase tempers of soapstone (Burke series) and sand (Cowan's Ford series) to have been intentionally added. David Moore also believes Burke potters might have added sand to their soapstone-tempered paste (personal communication) but to keep my analysis more clear, I used only either sand or soapstone to temper my tiles. Archaeologists can study temper as one part of a larger ceramic analysis or can focus their research solely on asking various questions about temper. What kinds of temper are represented

in the archaeological record? Where—in both time and space—were they used? What does the use of temper tell us about past societies?

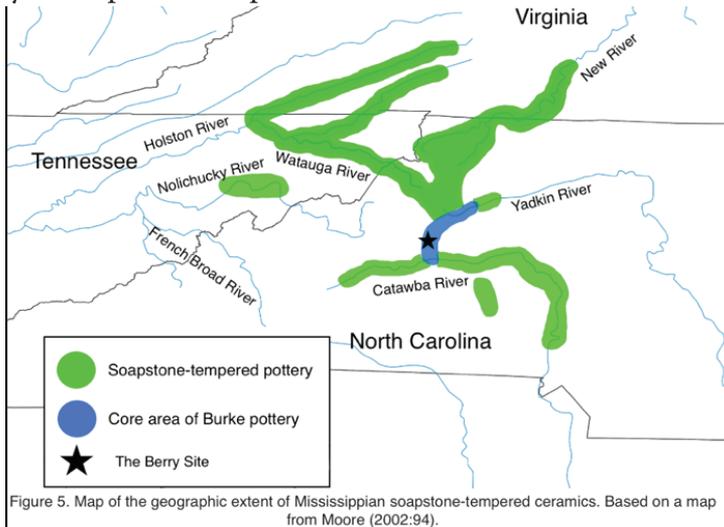


### *Soapstone and soapstone temper*

Soapstone is a metamorphic rock composed of 10-80% talc (Mathis 1981:3), which is what gives the rock its soapy, soft feel. Soapstone naturally occurs in the Blue Ridge/Appalachian Mountains and Piedmont areas from Alabama to Newfoundland (Moore 2002:264). Because it is very easy to carve with stone and bone implements, soapstone is a highly important material for groups of people across the Southeast and beyond. Indigenous peoples of the east coast of the United States took advantage of this locally available and easily malleable resource and made a variety of tools—e.g. bowls and pipes—and other goods (including beads, gaming disks, and chunky stones) out of soapstone.

Despite the widespread nature of natural soapstone and its frequent use across many different indigenous cultures in eastern North America, soapstone temper in ceramics remains

relatively rare for unknown reasons. Moore (2002:264) observes that “the distribution of naturally occurring soapstone has little, if any, correlation to the distribution of its use as a tempering agent” but has no explanation of this phenomenon. The use of soapstone as a temper ends sometime in the early colonial period as archaeological excavations of colonial Catawba towns have uncovered Cowan’s Ford and other sand-tempered pottery but no Burke series pottery (Riggs 2010). Previous research on soapstone has focused on soapstone bowls, quarries, or sourcing soapstone through mineralogical or other analysis. While individual soapstone tempered ceramic types have been studied, no regional study of soapstone temper has been done.



### *General Trends (and Gaps) in Archaeological Studies of Temper*

Archaeologists have used a variety of different methods and theories to answer questions related to temper. Some archaeological studies have maintained that the choice of different materials for temper, often assumed to be cultural, can be quantitatively linked to the function of the vessel (Bronitsky and Hamer 1986; Skibo et al. 1989; Hoard et al. 1995; Müller et al. 2010). A recent article by Bebbler (2017) detailed a functional analysis of temper, specifically in one variable: strength, while

also introducing cultural and contextual explanations of the choice of temper.

North American archaeologists have conducted many experimental studies of various temper materials, including limestone (Hoard et al. 1995); sand (Rye 1976), organic tempers such as Spanish moss, manure, and grass (Skibo et al. 1989), shell, sand, limestone, and grit (Bebber 2017; Bronitsky and Hamer 1986). I was not able to find any experimental studies of soapstone-tempered ceramics.

My study, while not exhaustive, provides an initial quantitative analysis of two performance characteristics of Burke phase ceramics: strength and thermal shock resistance. Burke series, Cowan's Ford series, and soapstone-tempered ceramics in general remain understudied areas within the ceramic analysis of Southeast and my research attempts to fill that gap by providing limited analysis of performance characteristics and an evaluation of cultural factors that constrained and enabled choice.

## **Experimental Archaeology**

### *Functional Interpretations of Choice*

Archaeologists have often turned to scientific experiments in order to test hypotheses about past peoples, especially when those hypotheses concern past technologies. These experiments are commonly referred to in archaeological literature as experimental studies and they focus on the pragmatic functions of various types of cultural materials. Experimental studies gained prominence in the 1960s, 70s and 80s under the paradigm of New Archaeology (Stark 1998: 4). An early work by Rye (1976) challenged the dominant idea that the “forms, decorations, and functions” (ibid: 106) of pottery were solely culturally determined. He argued that by examining the choices of material—and the knowledge that enables selection—archaeologists could better understand “the potter’s (and indirectly the culture’s) relationship to the natural world” (ibid: 106). The shift from a culture-based view of ceramic variation (in the form of temper) to function-based view was

further developed by Bronitsky and Hamer (1986). They tested experimental tiles containing different tempers to understand the “relation between temper selection and vessel function” (*ibid*: 90). Bronitsky and Hamer’s work was challenged on methodological shortcomings (e.g. use of commercial clay and “forming and firing procedures” [Feathers 1989: 581]) but not on the primacy of functional over cultural analysis. Functional analysis in experimental studies of temper proved to be very popular and researchers continued within that methodological paradigm in both the United States (e.g. Schiffer and Skibo 1987; Neupert 1994; Hoard et al. 1995) and in Europe (Müller et al. 2010; Tite et al. 2001).

Later experimental work by Schiffer et al. (1994) continued to focus on vessel function to explain variation but called for a more rigorous methodology and theory in experimental studies. Schiffer et al. (1994) recommend longer-term experimental studies and a “causal framework” that would contextualize “specific technological features” (*ibid*: 210). European experimental analyses of temper also responded to the need to combine cultural and functional variables while also providing “maximum encouragement” (Sillar and Tite 2000:17) to the scientific performance and production-based functionalist methodology. Sillar and Tite (2000) argue that the “material science” approach to experimental archaeology emphasized by some American archaeologists (Bronitsky and Hamer 1986; Hoard et al. 1995) was flawed in that it underestimated the need to thoroughly understand the cultural and social factors in the groups that they studied.

Bebber (2017) is a recent example of a study to answer the call to synthesize both cultural and functional analysis in technological variation in experimental analysis of temper. Bebber examined variation in temper through the lens of opportunity cost, finding that temper decreases vessel strength but has the advantages of “better size and shape formation, improved drying, prevention of warping, and elimination of blowouts during firing” (*ibid*: 11). This finding contrasts with the

dominant examination of performance-based over production-based benefits in previous experimental studies (e.g. Bronitsky and Hamer 1986; Hoard et al. 1995). However, Bebber (2017:12) did not only focus on functional analysis; she also took the “geo-temporal context” of the vessels into account. Bebber did not simply look at the data generated by her experiments in a vacuum but considered how the vessel’s function (a cooking vessel) would not have had to withstand long distance transport or that thermal transfer might be more important than strength for the vessel (*ibid*: 12). This new type of experimental analysis borrows greatly from non-experimental analyses of material culture.

### *Cultural Interpretations of Choice*

Non-experimental archaeological analysis of variation in material culture has often been examined through the lens of the *chaîne opératoire*, a French term for “deeply embedded operational sequences” (Stark 1998:5). In this tradition, material technology is not simply considered a physical object but “know-how, manual skills, procedures, but also... a set of cultural representations of ‘reality’” (Lemonnier 1986:154). Other culturally focused definitions of technology often focus on not just the material itself but on the inter-related knowledge and skills of the people that manufactured the material. This multi-polar view (though slightly different) of technology can also be seen in functionalist approaches to technological variation. Schiffer and Skibo (1987: 595) defined technology as “a corpus of artifacts, behaviors, and knowledge for creating and using products that is transmitted intergenerationally.” Dobres and Hoffman (1994:212) expanded the cultural definition of technology still further to “a fundamental medium through which social relationships, power structures, worldviews, and social production and reproduction are expressed and defined.”

The results of a cultural analysis of technological variation vary from each study and researcher. Lemonnier, a French anthropologist, argues that a study of technological material culture can provide observations about the social order

or socioeconomic system of the people within that culture (1986:154). Briggs (2016), researching the interrelations of foodways and ceramic vessel morphology and use-patterns, expanded that premise to incorporate macro-structures (e.g. hierarchy and kinship) but also less obvious, but no less important, structures of socio-cultural life; in this case, taste and foodways. Other researchers have argued that the practice of technology (including both material and social contexts of technology) tangibly expresses a culture's intangible worldview (Dobres and Hoffman 1994:220).

Another method of examining technological variation is to utilize a "community of practice" model developed by Wenger (2000). The community of practice model understands learning and knowledge as fluid and produced through the act of doing (or learning) in a group. This model has been used by many archaeologists in the Southeast, including Sassaman and Rudolphi (2001). In their study of Late Archaic period (3800-3500 B.P.) pottery in the Savannah River region of South Carolina and Georgia, they examined handedness (left or right) of potters using surface decorations of pottery as a community of practice. This method is less of an endpoint or conclusion and more of a paradigm or lens with which to view variation and choice in craft or technology and lacks interpretive power to describe the community and explain how and why it was formed, which is the heart of the question for archaeologists.

All of these issues of technology, knowledge, worldview, social practice, cultural identity, performance/production-based benefits, and cultural context are relevant to understanding the use of soapstone in Burke phase ceramics. Understanding the choice of soapstone temper in the Burke phase as a part of a deeply embedded operational sequence of skills, knowledge, and materials allows archaeologists to theorize about Burke phase people's relationships to the environment, society, and culture. Was the use of soapstone connected to the geographic availability of soapstone? How did the use of soapstone reflect societal organization or cultural identity? Archaeologists can

use experimental studies that evaluate functional benefits (performance or production-based) and supplement those results with culturally-influenced ideological contexts of the Burke phase.

## Methods

### *Introduction*

Why do two nearby pottery traditions, with many similar or identical choices, differ so greatly in one attribute? In this study, I conducted experiments on soapstone tempered ceramic tiles (representative of Burke series pottery), sand tempered ceramic tiles (representative of Cowan's Ford series pottery), and untempered ceramic tiles (for a control) in order to understand whether soapstone temper had a functional advantage over either sand tempered ceramics or untempered ceramics. I hypothesized that soapstone tempered (Burke series) ceramics are more resistant to thermal shock than untempered or sand tempered (Cowan's Ford series) ceramics and also that soapstone tempered ceramics are weaker than untempered ceramics but stronger than sand tempered ceramics.



Figure 6. Soapstone sorted into two size classes using geological sieves

Good experimental methods, both in the creation of ceramic tiles and in the testing of those tiles, work to achieve a balance between an understanding of the chemical and/or physical properties that temper might influence in ceramics

while remaining applicable to the specific examples of Burke and Cowan's Ford series ceramics. This allows the results of this research to be extrapolated to the specific contexts of Burke and Cowan's Ford series ceramics, not just hypothetical sand or soapstone-tempered ceramics. Likewise, if the goal of the experiment is to test a hypothesis about the function of a vessel, then the test must simulate (to our best understanding or guess) the function of that vessel as it was in the past. Thermal shock resistance, i.e. resistance to heating and cooling, is a very important variable to the function and performance of cooking vessels which would have been subjected to intense cycles of heating and cooling (Müller et al. 2014:263; Bebber 2017:12). The strength of ceramics is another important aspect of many kinds of ceramic vessels and would have been an important variable in vessel manufacture (Müller et al. 2010:2457). The experimental ceramic tiles were made with care to both eliminate variables that could influence the results of the experiment while also producing a product that is as close as possible to Burke and Cowan's Ford series ceramics.

### **Tile Production Methods**

#### *Soapstone Temper*

Soapstone temper for this experiment was manufactured by crushing samples of soapstone collected from a quarry in the Appalachian mountains of Vermont. Originally I intended to use soapstone found in western North Carolina but due to time and geographic constraints I decided to use soapstone from Vermont while I was there over winter break. This led to a minor incident at airport security when a zealous (and also furloughed) TSA agent grilled me

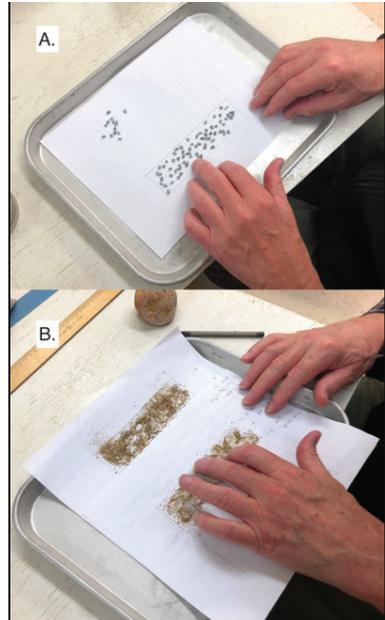


Figure 7. Determining concentrations of soapstone (A.) and sand (B.) temper.

about my ziplock bag of crushed soapstone that I tried to bring in my carry-on.

The soapstone was crushed using a quartzite river cobble and then sorted into different size classes (Fig. 6). The crushing of soapstone into smaller, temper-size particles leaves particles that have striking differences from archaeological specimens of soapstone temper. My experimental crushed soapstone is often angular and sharp where archaeological Burke temper is often more rounded. This could be due to weathering or firing but will be further discussed in my Limitations section.

There is an ongoing experiment in the WWC Archaeology Lab to chemically macerate samples of potsherds to measure the amount and characteristics of the temper within each sherd but presently the exact value of these variables are unknown. In the preliminary stages of this project, soapstone temper was sorted into categories of fine (1-5 mm), medium (5-7 mm), and coarse (7-10+ mm). Due to time considerations, this experiment forwent the coarse grade temper and just used the soapstone temper that had been sorted into the fine and medium categories.

The concentration of soapstone temper in Burke series ceramics noted by Moore had a wide range but “usually” was between 20% to 30% of volume (2002:258). Dave Moore and I determined the amount of temper to use in each tile by visually estimating amounts of crushed soapstone laid over 1:1 scale paper diagrams of the tiles and weighing the amount of temper that was judged to be the correct amount (Fig. 7a). I chose to produce two different concentrations of soapstone temper (a high and low) to approximate the wide range of concentrations of



Figure 8. The view from the bank of the Swannanoa River where I collected my sand samples

archaeological Burke series temper.

### *Sand Temper*

Sand temper in Cowan's Ford series ceramics is usually quartz-based with variable sizes of sand grains (coarse, medium, fine) and "low to medium" (Moore 2002:266) concentration within the ceramic paste. Sand for this experiment was collected from the Swannanoa River in western North Carolina (Fig. 8). Similarly to soapstone size considerations, I decided to just use fine and medium grades of sand for temper. I collected sand from two different areas of the river to obtain a variety in the sizes of particles. I collected fine-grained sand from the shallow area near the bank of the river and coarser, medium-grained sand from the middle of the river, where the water was deeper and the current was more swift. The sand was left out to dry on trays of newspaper to remove all the moisture from the sand prior to the tile production (Fig. 9). The amount of sand temper to be used in the high and low concentrations of temper used the same method as the soapstone temper (Fig 7b).

### *Clay*

I used Earthenware Red clay, a low-fire earthenware made by Highwater Clays, a regional producer and distributor of clay to the modern Southeast, to produce the tiles. There has been debate about



the use of commercial clay versus local clays that are prepared by archaeologists to simulate ancient clays used by potters. Some archaeologists feel that commercial clays will standardize results and are the only proper clay to use in experimental archaeology (Skibo et al. 1989:124; Schiffer et al. 1994:200). Other archaeologists feel that the only appropriate clays to use are local

clays that approximate the ancient clay used by potters (Bebber 2017:2; Feathers 1989:580). Due to the limited time frame of this study, commercial clay was used. Further studies should consider the use of local clays similar to those used by Burke potters in the past and modern Catawba potters in the present.

Overall, the methods behind the production of the tiles attempted to strike a balance between eliminating variables and making the results of this research replicable while also retaining an “actualistic” (Outram 2008:2) approach that attempts to use materials and methods that would have been available to Burke potters. Without both standardizing and

actualizing these tiles, the experimental tests would not be able to be applied to the specific functions of pottery from two ceramic traditions along the Catawba River in the late Mississippian period (1400-1600 B.C.E.).

Figure 10. Crushed soapstone temper before it was added to the clay



Table 1. Test groups with corresponding temper kinds/concentrations and the number of tiles in each group

Test Group	Temper	Number
MSpH	High concentration of medium-sized soapstone temper	12
MSpL	Low concentration of medium-sized soapstone temper	12
FSpH	High concentration of fine-sized soapstone temper	13
FSpL	Low concentration of fine-sized soapstone temper	12
MSdH	High concentration of medium-sized sand temper	13
MSdL	Low concentration of medium-sized sand temper	12
FSdH	High concentration of fine-sized sand temper	12
FSdL	Low concentration of fine-sized sand temper	13
X	Untempered (control)	18

### *Tile Production*

The tiles were made by first wedging the temper into the clay (if necessary) (Fig. 5). The wedged clay was then put in a slab-roller and rolled flat to a quarter inch thick. A handheld 6" x 6" square tile cutter was used to partition the clay into squares that were then divided into 4 equal parts. Each tile ended up being 6" long, 1.5" wide, and .25" thick. In total, I made nine separate test groups with different kinds and amounts of temper (see Table. 1). To keep them separated during the production and testing phases of my research, I gave each group a code that I wrote on each tile with a black ceramic stain.

### *Firing*

The tiles were dried and then fired to 1485°F (807°C). This temperature was chosen because it approximately represents the higher end of pit-firing and similar numbers have been used in other studies (Bebber 2017:8; Bronitsky and Hamer 1986:91; Skibo et al. 1989). Firing temperature is known to greatly affect the strength of ceramic. Therefore, an advantage of a firing temperature below 1650°F (900°C) is that the ceramic will not vitrify, which would improve the strength beyond what would have occurred for Mississippian potters (Rye 1976:111).

## **Experimental Methods**

Two different but related experimental tests were used to gain insight into the reasons why the potters who produced Burke and Cowan's Ford series pottery utilized soapstone and sand temper respectively. Both strength and thermal shock resistance were tested.

### *Strength*

Strength is an important variable for the function of ceramic vessels due to the fact that easily broken or flimsy vessels would have been highly undesirable and quickly discarded by ancient potters. This is less important in cooking and storage vessels than vessels involved in long distance transport but still an important consideration (Bebber 2017:12). Strength has been

measured through many different methods in different experiments by different researchers. While some (e.g. Bronitsky and Hamer 1986; Skibo et al. 1989) used impact tests, others have argued against the procedure due to imprecision (Feathers 1989:581; Neupert 1994:712). Testing ceramic strength through specifically designed testing machines that apply and measure force to an object is a preferred method for many archaeologists (e.g. Bebbber 2017; Bronitsky 1986; Feathers 1989; Müller et al. 2010).



Figure 11. A tile in the testing setup at WCU

In this study I used such a machine to test strength through measuring modulus of rupture, or “the fracture strength of a material under a bearing load” (Bronitsky 1986:235). By comparing the modulus of rupture of differently tempered ceramic tiles, we can make inferences about the relative strength of the ceramics those tiles are representing. Another advantage of strength testing through this method is that similar methodology and equipment can be used to measure thermal shock resistance.

To do the test, I traveled to the Center for Applied Technology (CAT) at Western Carolina University (WCU). Dr. Jane Eastman, an archaeology professor at WCU who has done previous work in experimental ceramics, introduced me to Monty Graham, the Engineering Project Coordinator at WCU CAT who had previously worked with Dr. Eastman on similar projects. Mr. Graham, Dr. Eastman, and I collaborated to design a three point flexural test using an INSTRON 5967 universal testing machine to calculate the flexural strength (modulus of rupture) of my tiles. The tiles were positioned so that the middle of the tile (which had been marked and measured to find the cross-sectional area) was directly under the crosshead of the machine. The tiles rested on two support spans 4.423” apart and the crosshead was carefully

lowered until it rested on top of the tile without imparting any force onto it. The crosshead was lowered at a displacement of 5 mm/minute and the load of the crosshead was measured in newtons (N). See Fig. 11 for a photo of the testing machine and setup. The load over displacement (of the crosshead, not the tile) was then sent to an Excel spreadsheet using software attached to the testing machine (Fig. 12).

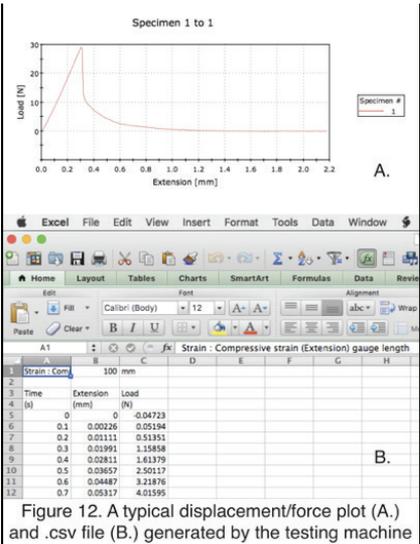


Figure 12. A typical displacement/force plot (A.) and .csv file (B.) generated by the testing machine

### Thermal Shock Resistance

Thermal shock resistance is a very important characteristic for the function of pottery. Thermal shock comes from exposure to extreme heating or cooling. This can happen through the use of the vessel (e.g. during cooking) but will undoubtedly occur during the firing process at the beginning of the vessel’s functional life. Thermal shock resistance can be defined as “a measure of the ability of a material to withstand rapid changes in temperature” (Müller et al. 2014:263). Temper is widely acknowledged to have some effect on thermal shock resistance (Bronitsky 1986:253; Müller et al. 2014:265; Rye 1976:115–116; Schiffer et al. 1994:200); this hypothesis has been tested by many different researchers within the context of specific types of pottery in different geographic areas (e.g. Bronitsky and Hamer 1986; Müller et al. 2010; Müller et al. 2014; Skibo et al. 1989; Schiffer et al. 1994).

In this study, I measured thermal shock resistance by exposing experimental ceramic tiles to quick cycles of heating and cooling. The tiles were then strength tested using the same procedure as the previous strength test and will allow me to measure the amount of “strength degradation” (Bronitsky

1986:258) stemming from the thermal shock. Several other archaeology researchers have used this methodology to test experimental hypotheses about temper function (Bronitsky and Hamer 1986; Skibo et al. 1989; Tite et al. 2001). Bronitsky and Hamer were among the first to outline an experimental procedure to test thermal shock resistance of pottery. In their study, they immersed ceramic tiles in boiling water for five minutes and then immediately quenched in ice water. This heating and cooling cycle was repeated 20 times and then strength degradation was tested using the impact test with a pendulum. Skibo et al. (1989) used the same procedures in their experiment but increased the amount of cycles to 40 (ibid 1989:132). Müller et al. used a slightly different methodology which involved heating tiles at 430°C (806°F) for twenty minutes, cooling them in water (27-30°C), letting them cool for five minutes, drying the tiles at 115°C for 20 minutes, and then repeating this cycle five times (2014:267).

In my study, I initially tried to follow Müller et al.'s (2014) method as I felt it was the most clearly delineated and precisely replicated. I tried to use my oven in my dorm room kitchen to heat the tiles, despite the fact it would only go up to 550°F (287°C), because I did not have a better option. However, after I pre-heated the oven and put the tiles in, the fire alarm immediately went off in my building. This resulted in an awkward conversation with WWC Public Safety officers and the local Swannanoa Fire Department.

As a result of this, I chose to follow Bronitsky and Hamer's (1986) method, though I modified it by only doing five cycles instead of 20. Even after just a few cycles I quickly noticed cracking and spalling (pieces of tile popping off) beginning to occur and concluded that five cycles would be enough to have a measurable effect. This method was chosen because it was simple to do and did not require equipment that I did not already possess. I did try to find an alternate oven or furnace that I could use to heat the tiles but the furnaces in the Chemistry department of WWC were too small and impractical for this experiment.

Obviously, this test was not my first choice to test thermal shock resistance. The boiling and ice water test does not exactly replicate the exact use of Burke pottery. It is not likely that people at that time cooked their food in five minutes and then submerged their cooking pots in ice water. However, the stresses that the repeated temperature change of the tiles induced by this experiment would likely be similar (if exaggerated) to the stresses that Burke ceramics would have to go through on a daily basis, not to mention to survive the process of pit firing.

Additionally, while the test is not 100% accurate to the conditions of use by past Burke peoples, some similarities can be seen. In Briggs' (2016) study of the transition between West Jefferson phase jars and Moundville phase jars in the Black Warrior valley of Alabama, the Mississippian Moundville phase jars were very well adapted to indirect fire heat and the hominy foodway, which involved boiling maize and wood ash or lye. This foodway would likely also have been present in the Burke phase and at least a component of Burke phase subsistence, due to the high frequency of maize kernels found at the Berry site (Beck et al. 2016).

### **Statistical Analysis**

In order to effectively compare my data between groups I performed statistical analysis using the statistical program, R Studio. I used several different analysis of variance tests to assess variation across the different temper types and concentrations of each sample group (hereafter referred to as groups).

Initially, to determine if there was variance between and among non-thermal shocked groups of flexural strength, I did a one-way ANOVA test. This test has been performed to analyze other similar archaeological experiments, e.g. Bebbler (2017:8). After talking with Thomas Robacker, a Warren Wilson College professor of statistics, and examining the literature of other researchers who have done similar experiments e.g. (Neupert 1994:715), I decided to also perform a Kruskal-Wallis test. The Kruskal-Wallis test is similar to one-way ANOVA but it is not

parametric, meaning it does not require the same assumptions as the ANOVA. It also does not require as large a sample size as the ANOVA. However, the Kruskal-Wallis does require Bartlett's assumption of homogeneity test, which was also performed prior to the Kruskal-Wallis.

To examine differences between strength of thermal shocked groups and non-thermal shocked groups I performed a two-way ANOVA test. This test is parametric and as such, the results are more questionable due to my studies' small sample size but I did not have another option.

## **Results**

The goal of this study was to investigate why Burke phase potters used soapstone as a temper in their pottery. The experimental side of this investigation aimed to answer that inquiry through a functional lens, focusing on this question: did soapstone temper create a beneficial "performance characteristic" (Schiffer and Skibo 1987:599) for Burke phase potters?

Experimental archaeologists have examined similar questions around temper among many other different groups and time periods (e.g. Bebbler 2017; Bronitsky and Hamer 1986; Feathers 1989; Hoard et al. 1995; Müller et al. 2010; Skibo et al. 1989). The most frequently analyzed variables are strength and thermal shock. The tests for each are easy to execute and both characteristics are recognized as important, especially in the Mississippian period. Strength is always important for ceramics but the introduction of temper often results in a decrease in strength (Bebbler 2017:2). Thermal shock resistance is also widely recognized as an important characteristic for Mississippian potters (Schiffer and Skibo 1987:607). Examining both strength and thermal shock is important for beginning to understand why soapstone was used as a temper by Burke phase potters.

In order to compare the data, I calculated the modulus of rupture for each tile using the formula in Figure 13. This formula finds the Modulus of Rupture (also known as Flexural Strength) for a rectangular prism in a three point bend test

using cross-sectional area of the breaking point, load at fracture point, and lengths of the support span which the tile rested on in the three point configuration (Bronitsky 1987:236). I then performed several

$$\sigma = \frac{3FL}{2bd^2}$$

$\sigma$  = flexural strength

$F$  = load (force) at the fracture point

$L$  = length of the support span

$b$  = width of the tile

$d$  = thickness of the tile

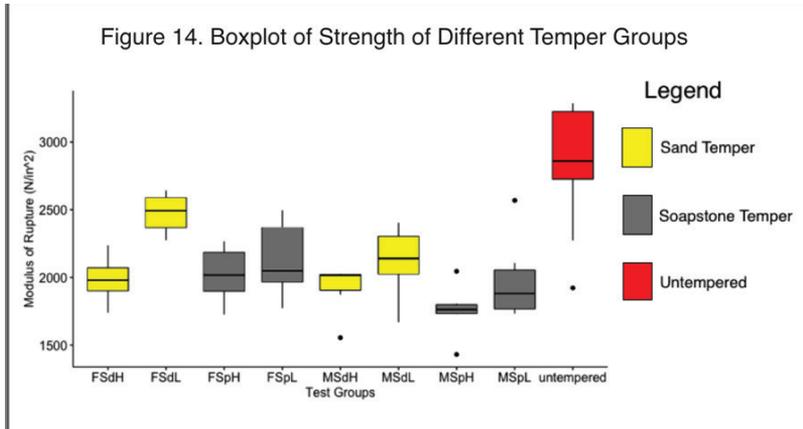
Figure 13. Modulus of Rupture formula

different statistical analyses on the data. For a more in-depth explanation of why I chose a particular statistical test, see the methods section, above. In addition, for an example of what each Test Group represents, see Table 1 in my Methods section.

### Strength

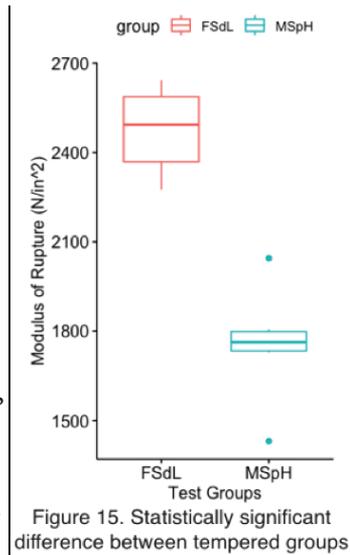
For a simple visual perspective, the untempered control ceramic tiles were clearly the strongest. This is clearly shown in Figure 14, a boxplot of the different temper groups versus Modulus of Rupture (MOR). The higher the MOR, the greater the strength needed to break a tile. The boxplot-style graph represents the first quartile of data as the bottom “whisker” of the boxplot, the lower section of the box as the second quartile, the thick centerline of the box as the median value, the upper section of the box as the third quartile, and the upper “whisker” as the fourth quartile. The two medium-sized soapstone tempered tiles (MSpH and MSpL) were among the weakest groups. This conclusion is backed up by the statistical analysis. Both the one-way ANOVA ( $p < .001$ ) and the Kruskal-Wallis tests ( $p = 2.372e^{-5}$ ) concluded that there was a statistically significant difference between the strength of one or more of the temper groups. However, neither test indicates *which* groups are significantly different. To determine that, I had to do a post hoc analysis for which I chose to run the Dunn test with the Bonferroni correction. The post hoc analysis identified four variations of groups that were statistically significant. The fine-sized, low concentration, sand tiles (FSdL) were stronger than the medium-

sized, high concentration, soapstone tiles (MSpH) (Fig. 15). The untempered tiles were significantly stronger than the medium-sized soapstone tiles (both high and low concentrations) and the medium-sized, high concentration sand tiles (Fig. 16).

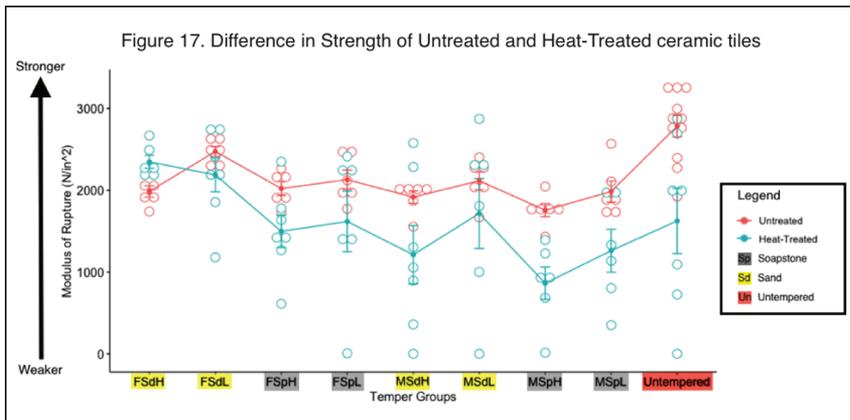
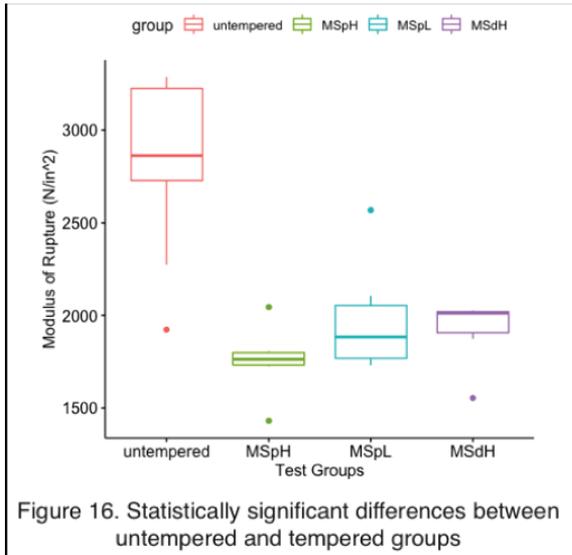


### Thermal Shock Resistance

A simple visual trend can also be seen with respect to thermal shock resistance. Figure 17 illustrates this in a line plot of MOR of each temper group. Tiles that underwent thermal shock (TH) are colored blue and tiles that did not undergo thermal shock are red. The tiles that underwent the thermal shock were generally weaker than those that did not. The fine-sized, high-concentration, sand tiles (FSdH) were a notable exception to this trend.



However, this conclusion must be examined statistically in order to make any convincing arguments about the effect of thermal shock on temper. Unfortunately, this data is too spread out to determine any significant differences. The spread of each thermal shocked temper group is wide and often overlaps with the non-thermal shocked group.



## Discussion

Recent experimental research has indicated that the addition of temper decreases the strength of the ceramic (Bebber 2017). The results of this experiment have backed up this conclusion. In this study, untempered tiles are generally stronger than most tempered tiles. In particular, untempered tiles are proven to be significantly stronger than medium-sized, high-concentration sand tiles, medium-sized, low-concentration soapstone tiles, and medium-sized, high-concentration soapstone

tiles.

Why would Burke potters have chosen to temper their vessels and why temper with soapstone, a rarely-used tempering material, given this decrease in strength? There are many possible reasons, as strength is just one characteristic of ceramics. When determining the reasons for technological change, Schiffer and Skibo (1987) advocate for evaluating all performance characteristics and values to determine “patterns of compromise” (*ibid* 1987:601). While Burke potters might have known their vessels would lose strength, soapstone temper could have aided their pottery in other characteristics. Archaeologists point out that temper provides many beneficial characteristics for the producer of the ceramics, e.g. workability of clay, reduction of warping, facilitating drying and firing, and for the user of the ceramics, e.g. thermal shock resistance, durability, thermal conductivity (Shepard 1985: 131; Bronitsky and Hamer 1987:90; Rice 1987:412; Schiffer et al. 1994:200; Tite et al. 2001:232; Bebber 2017:12). It is possible that soapstone temper provides an advantage in one or more of those areas that was especially desirable to Burke phase potters.

Perhaps strength was not even an important factor for Burke phase potters. It is possible that the increase in strength offered by untempered pottery would have been considered “over-engineered” (Bebber 2017:12) by Burke phase potters and not necessary for production or use of the ceramics.

Clearly, the analysis of a single factor or characteristic is not enough to determine why a technical choice, such as the use of soapstone temper, was made (Schiffer et al. 1994:210). Many experimental archaeologists have called for both production and performance benefits of temper and other technical choices in material culture to be researched (Schiffer and Skibo 1987:600; Sillar and Tite 2000:5; Feathers 2006:126; Bebber 2017:2) and specifically thermal shock resistance (Hoard et al. 1996:829-830). Understanding more about the specific factors that influence pottery production and use will allow archaeologists to draw more holistic and complete interpretations of specific ceramic

traditions.

In addition to the production and performance characteristics of Burke phase ceramics, the socio-cultural context of those factors needs to be explored in order to gain a fuller understanding of why Burke phase potters selected soapstone to temper their wares. Many of the same archaeologists advocating for a better quantitative understanding of temper also recognize the importance of cultural factors and interpretations (Rye 1976:106; Schiffer and Skibo 1987:600; Sillar and Tite 2000:9; Bebbler 2017:2). There have been many cultural interpretations of the use of temper, including marking visual distinctions between the material culture of different groups (Rye 1976:106; Bronitsky and Hamer 1987:90).

However, archaeologists have also advanced other cultural interpretations of temper use. For instance, the use of soapstone temper for preserving economic or cultural systems can be seen in Marcey Creek ceramics in the middle Atlantic region. Although this ceramics style occurred thousands of years before the Burke phase, some suggest that the soapstone temper in Marcey Creek pottery represented an attempt on the part of the producers of the pottery to maintain soapstone exchange networks during the transition from soapstone bowls to ceramics (Klein 1997:147). Not only did Marcey Creek ceramics utilize soapstone as temper but they also mimicked form and style attributes of soapstone bowls, despite performance-based opportunity costs, especially related to thermal shock resistance (Klein 1997:145). This suggests that potters were willing to sacrifice vessel performance to maintain larger socio-cultural systems. It is possible that soapstone temper in Burke phase ceramics functioned in a similar way although more work needs to be done to identify their specific motivations (e.g. Mississippian-period soapstone exchange networks).

Other work on soapstone temper in areas outside the Burke phase has been done by Kaiser (1989) and Borowski et al. (2015). Kaiser proposed that the unique soapstone tempered pottery found at one site in Serbia represented a "Neolithic

experiment in ceramic design." (*ibid* 1989:1). Soapstone tempered Vinča pottery had a short period of use and co-occurred with other short-lived tempers (Kaiser 1989:8). This is unlike Burke series pottery which was ubiquitous across the phase and the dominant form of temper at Burke phase sites. Borowski et al. (2015) highlighted the potential thermal properties of soapstone temper in a petrographic analysis of Stroke Ornamented Ware (SBK) in Neolithic Poland. The qualities they identified—low coefficient of thermal expansion, insulation, high latent heat retention, ease of quarrying (due to low hardness) (Borowski et al. 2015:208)—all could apply to Burke phase soapstone tempered pottery.

David Moore has observed that the visual effect of soapstone temper in Burke vessels bears a striking resemblance to Mississippian shell-tempered pottery. He has proposed that by adding the soapstone temper, Burke phase potters may have attempted to replicate the appearance of Mississippian shell-tempered Dallas type vessels from east Tennessee (personal communication). Thus, Burke phase pottery can be understood as a local adoption of a regional shift in (Mississippian) material culture.

Other researchers have argued that local practices that go against the hegemonic Mississippian classification—“flat-topped mounds, shell-tempered pottery, and exotic trade goods” (Meyers 2002:178)—could represent a spectrum of resistance or accommodation of Mississippian culture. Du Vernay and White (2017) argue that the presence of Late Woodland elements into Mississippian Fort Walton material culture indicate, “an assertion of local identity while participating in the wider Mississippian world” (Du Vernay and White 2017:286). Related to this idea is the conceptualization of the Burke phase (and others like it) as a Mississippian “frontier” (Beck and Moore 2002; Meyers 2002; Meyers 2017). In this view, the regional differences of Mississippian phases might represent the boundaries of Mississippian power and influence.

Other archaeologists, e.g. Whyte (2015; 2017), have

pushed back on “lumping” ceramics into groups based on a few characteristics like temper, surface treatment, and rim decoration. Whyte (2017) advocates for an approach that instead considers those characteristics as decisions made by potters based on social networks, “raw materials and technologies available for production, and social expectations or restrictions” (*ibid* 2017:162). This assertion is backed up by Worth (2017), while not a wholesale rejection of ceramic types, suggesting that other paradigms like community of practice—“shared histories of learning and practice, as manifested materially as a locus formed by the intersection of multiple horizons of practice reflected in the spatial distribution of material culture produced by this process” (*ibid* 2017:151)—might allow for other interpretations of material culture. This paradigm shift may be especially useful when the standard ceramic typologies fail to allow for an adequate interpretation, as in the case of Whyte (2015; 2017).

Trying to account for ceramic variation through the lenses of these different theories (accommodation/resistance, the frontier, typological “lumping”) might seem dissonant, but in reality, they reflect a tendency to include local practices and knowledge into the interpretation of material culture. This approach is not new in archaeology. Binford (1962) argued for seeking out interpretations of the “local adaptive situation” rather than normative explanations (*ibid* 1962:20). A focus on local systems of knowledge and practice, combined with the larger landscape of cultural power and influence, is crucial to understanding the use of soapstone temper in Burke ceramics.

While these paradigms and theories might be useful in abstract, a more complete interpretation will include how and why these communities of practice have formed. This should be demonstrated by careful archaeology of transitional periods within traditions of material culture. This has already been done by many archaeologists in different areas including Du Vernay and White (2017) for the Late Woodland to Mississippian transition of Fort Walton culture, Briggs (2016) for the transition between Late Woodland West Jefferson jars and Mississippian

Moundville jars, and Riggs (2010) for the transition between Mississippian and colonial period of the lower Catawba River. Previous research into the Burke phase—e.g. Moore (2002) and Beck and Moore (2002)—did much to develop a chronology of the Burke phase but far more remains to be done to understand the entire range of Burke phase material culture.

Experimental archaeology aims to illuminate possible interpretations of cultural processes dealing with material culture. Due to constraints like a limited sample size and the limiting factor of only analyzing a few characteristics, a complete answer to the question of why Burke phase potters used soapstone temper is impossible. Soapstone tempered ceramics have been shown to lose strength when compared to untempered and sand tempered tiles. This loss of strength would have been understood by Burke phase potters as a necessary opportunity cost for some functional or cultural advantage. There are many potential explanations for this choice but they must be investigated with further archaeological study, including both more experiments measuring the quantitative benefits of soapstone temper and an examination of the transitional period between the late Woodland and Mississippian periods in the upper Catawba valley.

Ideally, all archaeologists should work in collaboration with the descendant communities of the ancestors they are studying, to generate research that is respectful and benefits the field of archaeology and the descendant community equitably. Archaeologists have too seldom taken the wishes or interests of the descendant communities into account when undertaking research. Archaeologists and community members should work together to generate research questions that are useful to both parties. At a minimum, archaeologists should communicate with the descendant communities to determine their interest in participation or what benefits the research could provide to the community.

Unfortunately, establishing a collaborative relationship, as described above, was beyond the scope of this project but should

be done in any future research, especially with respect to cultural interpretations of the choice of soapstone temper by Burke phase potters. Modern Catawba Nation potters are famous for their long tradition of ceramic production, from at least the Burke phase, to the colonial period, and surviving into the present (Blumer 2004, The Catawba Nation 2012). Through partnership with modern Catawba potters and traditional cultural knowledge keepers, archaeologists can gain invaluable insight into their perspective of their ancestors. The Catawba Nation, according to their level of interest and also any research questions they have, also could benefit from future collaborative research.

### **Conclusions**

The aim of this research is to quantitatively assess relevant performance characteristics that Burke phase potters would have taken into consideration when selecting a temper. I have found that soapstone temper represents a loss of strength and not been able to demonstrate a significant advantage in thermal shock resistance. That is not to say those two characteristics are the only two that might have mattered; there are many others that could have been important to Burke potters: porosity, durability, workability of clay, etc.

In addition, cultural factors could have influenced the selection of temper. If a significant performance benefit of soapstone temper can not be demonstrated, we should look to a cultural explanation. Temper might have been a good way for Burke people to distinguish between the people who lived on the upper Catawba (soapstone-tempered Burke series) and the lower Catawba (sand-tempered Cowan's Ford series). Soapstone could have been tied to important systems of trade and exchange, like in the Late Archaic Coastal Plain of Georgia and South Carolina. Soapstone temper might have evoked a Mississippian style while asserting a local identity on the margins of the Mississippian world. There are many other possible interpretations but until more archaeological work is done, the definitive reason behind soapstone temper in Burke series pottery remains evasive.

This is also complicated by the fact that both cultural and performance characteristics were likely considered to be important to Burke phase potters and might had a recursive relationship to one another. This is likely not an either-or question; there may be more than one correct answer.

Instead of proposing a definitive answer to the question of Burke series soapstone temper, I advocate for an organizing principle of how to understand performance characteristics and cultural factors and the interaction between them. The definition of something as concrete and quantitative as “performance characteristics” might seem fairly obvious: a distinct and measurable boost—or decrease—in the function of an object (a vessel, projectile point, really any kind of material culture). “Cultural factors,” however, is a vague term that implies performance characteristics would not have been considered culturally important.

In reality, they influence each other and must be examined as such. Other experimental research has measured the quantitative characteristics to determine the “opportunity-costs” of temper (Bebber 2017). Other researchers have argued for comparing performance characteristics to the ‘functional field,’ “the set of techno-functions, socio-functions, and ideo-functions that the artifacts in a society have to perform” (Schiffer and Skibo 1987:598) to determine “patterns of compromise” (ibid 601). My research does not prioritize one over the other but instead looks at the interaction between performance characteristics and other socio-cultural systems such as exchange and identity to understand technological choice and variation.

In this way, soapstone temper in the Burke phase can be seen as an effort to manipulate both performance characteristics and cultural functions by Burke phase potters. These choices should be understood as intentional and thus reflective of ideas, values, and realities of Burke phase potters.



## Acknowledgements

I could not have imagined this research being completed anywhere but Warren Wilson College. What has been so special about this project has been the diverse network of professors, staff, and work crews that have helped this process along from the very beginning. They have had an indelible impact on the directions and methods of this research.

Naturally, Dr. David Moore, Abra, and the Archaeology Lab crew were crucial to this project and I cannot thank them all enough. Additionally, I have received advice, borrowed equipment, and bounced ideas off of the Ceramics Studio Crew and Leah Leitson, Bio/ENS Crew, Thomas Robacker, and Chemistry Crew. This research has been very interdepartmental, from the arts to anthropology to chemistry and back to archaeology. It has crossed several academic divides on Warren Wilson and brought me to people and places I had never interacted with in my previous three and a half years here.

To me, the most special aspect of this project has been that it demonstrates how Wilson's mission of combining academics, work, and community can lead to a whole that is greater than the sum of its parts. I have come away from this research more grateful for this realization than any anthropological or archaeological discovery.

Additionally, I want to thank Dr. Jane Eastman and Monty Graham of Western Carolina University. They were extremely generous to me and their help was pivotal in the design and successful implementation of the experimental portion of my research.

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**“Untitled” by Rebecca White**



# Exploring Mathematics through Knitting

## Abstract

The persistent disparity in gender representation in STEM occupational fields despite equal performance measures in education statistics suggests the existence of underlying cultural biases at play. This is most frequently addressed by psychology research on math anxiety and stereotypes of gendered personality traits; however, a closer look at classroom tools used to teach elementary math presents an area of research for developing education practices to encourage gender inclusivity by incorporating the use of handcrafts with inherent mathematical qualities. My research focuses on the mathematical properties involved in knitting, historically used for garment construction, and examines the craft's value as a learning tool spanning elementary concepts to high level abstract research. The mathematical applications discussed in this research are scaling, knot theory, cryptography, and modeling geometric surfaces, including Euclidean, Elliptic, and Hyperbolic. I explored these applications through many hours of knitting, examples of which I shared during my presentation. The knitted models, which included a set of interlocking surfaces, a torus, an encrypted message, and a demonstration of Reidemeister's Theorem using t-shirt yarn, served as concrete tools for my audience to engage with abstract concepts.

## Aquilla Sellew



Aquilla graduated with a BA in Mathematics in 2019. She currently uses her math background as a bookkeeper and waitress, juggling expense entries and entrees, in Athens, Ga where she lives with her gorgeous dog Ramona (pictured, but now a bit larger).

## Introduction

Like most areas of academia, mathematics is a male-dominated discipline. Despite evidence that there is no innate difference in mathematical ability between genders, this bias still persists in both higher education and professional working environments.<sup>1</sup> Mathematics is often categorized as a field of pure reason, free of any emotional contaminant that humans would naturally bring to their work. “True” math, which is what mathematicians aspire to, might meet these descriptions, but since humans are the ones performing the math, the work is inherently tainted with the biases and egos of the mathematicians.

Reason, the paramount value of mathematics, is a personality trait historically associated with masculinity.<sup>2</sup> Emotion, thought to be the opposite of reason, is the feminine complement.<sup>3</sup> Throughout history, women have been excluded from leadership positions and denied physical, social, and financial autonomy based on their “emotional” nature. “Hysteria,” coined in the 5th century BC from the Greek *hystero*, meaning the uterus, was a medical condition used until the twentieth century to scientifically diagnose women with “excessive

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1. Beth Azar, “Math + Culture = Gender Gap?” *Monitor on psychology: a publication of the American Psychological Association* 41, no. 7 (July/August 2010); H. Mendick, *Masculinities in mathematics*. Maidenhead, Berkshire, England: Open University Press, 2006. In the former paper, the term gender refers primarily to the differences that arise from social or environmental influences of a binarily structured society. This paper uses the terms “male” and “female” to distinguish these differences. This does not exclude the biological distinctions between people, but rather acknowledges that in our society biology cannot be separated from its cultural influences (Halpern, Benbow, Geary, Gur, Hyde, & Gernsbacher, 2007). It is presumed throughout this paper that the latter has greater influence on a person’s internalized view of self, which in turn influences the way an individual negotiates their personal, and subsequently academic and occupational, identity.

2. Alan Peterson, “Research on Men and Masculinities: Some Implications of Recent Theory for Future Work,” *Sage Journals* 6, no. 1 (2003): 54-69, doi:10.1177/1097184X02250843.

3. Mathematically, a complement is the amount you must add to something to make it whole.

emotion,” “overdramatic or attention seeking behavior,” and other negative qualities associated with femininity.<sup>4</sup> These qualities are considered unfavorable in mathematics, and so historically there has been little room for women in the discipline. It is now understood that women, like all humans, are rational beings.

### **Existing Genderedness in Mathematics**

Today in occupational statistics, we see the residual effects of the cultural narrative of women as emotional rather than rational. While the quantity of STEM (Science, Technology, Engineering, and Math) occupations has grown dramatically in the past fifty years, the employment ratio remains skewed in favor of men. Women’s representation in STEM fields has increased since the 1970s, according to a report published by the U.S. Census Bureau, but “they remain significantly underrepresented in engineering and computer occupations, occupations that make up more than 80 percent of all STEM employment.”<sup>5</sup> This data might suggest that women lack the skills that make people hireable in these fields. However, the National Center for Education Statistics reports that girls on the middle and high school level perform equal to or better than their male counterparts on math and science national assessments. This, combined with the fact that girls are more likely to pursue and obtain degrees in higher education, clearly indicates the issue is not that women lack qualification or natural skill.<sup>6</sup> In spite of this, among science and engineering graduates, men are hired at twice the rate of women

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4. Cecilia Tasca et al. “Women and Hysteria in the History of Mental Health,” *Clinical Practice and Epidemiology in Mental Health : CP & EMH* 8, (2012): 110–119, doi:10.2174/1745017901208010110.

5. Liana Landivar, “Disparities in STEM employment by sex, race and Hispanic origin,” *American Community Survey Reports* (Washington, D.C.: U.S. Census Bureau, 2013), 5; While the focus here is on gender, it should be acknowledged that there is a “significant underrepresentation of women, Blacks, and Hispanics in STEM employment” (Landivar, p. 1).

6. Allison Mann and Thomas DiPrete, “Trends in Gender Segregation in the Choice of Science and Engineering Majors,” *Social Science Research* 42, no. 6 (2013): 1519–1541, doi:10.1016/j.ssresearch.2013.07.002.

in STEM fields.<sup>7</sup> The data above suggest that there are social and cultural biases informing women that they are not welcome in these disciplines.<sup>8</sup>

As awareness is drawn to the need for more female representation in STEM, recent research on the value of handcrafts as means to explore and demonstrate mathematical concepts is rapidly gaining attention. Women have a deep historical connection to textile crafts, which are inherently "rich with mathematical thinking and problem solving."<sup>9</sup> By exploring examples of mathematical properties modeled effectively through knitting, we can begin to acknowledge the value of this craft as a tool for demonstrating and acquiring a deeper understanding of many levels of mathematical thinking.

### **Essence of Knitting**

Knitting stems from a large family of fiber crafts used as means of fashioning natural fibers into functional cloth, the earliest forms of which were weaving and sewing. Sewing, which uses one needle, led to a process called nalbinding, whose product is visually similar to that of knitting, which many agree is its two-needled progeny.<sup>10</sup> Knitted fabric is formed from rows of interlocking slipknots stacked on top of each other, created by a continuous strand of fiber looping back and forth upon itself. Each loop is a stitch, which, since it is curved and can slide onto its neighbors, creates a finished material that allows for a lot of

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7. Liana Landivar, "Disparities in STEM employment by sex, race and Hispanic origin," *American Community Survey Reports* (Washington, D.C.: U.S. Census Bureau, 2013), 2.

8. Mann and DiPrete; Beth Azar, "Math + Culture = Gender Gap?" *Monitor on Psychology: a Publication of the American Psychological Association* 41, no. 7 (July/August 2010).

9. Melissa Gresalfi and Katherine Chapman, "Recrafting Manipulatives: Toward a Critical Analysis of Gender and Mathematical Practice," paper presented at the 9th International Mathematics Education and Society Conference, Volos, Greece, April 2017.

10. "The History of Knitting Pt 1: Mysterious Origins," *Sheep & Stitch* online, last modified February 14, 2016.

stretch and flexibility.<sup>11</sup> This is different from woven fabric, where threads are crossed over and under each other perpendicularly so that the tensility is similar to that of the original fiber.<sup>12</sup> The elasticity of knitting makes it ideal for garments because the material conforms to the human shape (think of socks, or a stretchy hat).

Pulled from the left needle, an existing stitch is used as the base to form a new stitch, which is transferred onto the right needle as the first stitch is moved off the needles to become a part of the growing fabric. This process of yarn moving through needle is often learned through rhyme as a child – *In through the front door, once around the back. Peek through the window, off jumps Jack* – but its essence is thoroughly mathematical.

### **Knot Theory in the Stitch**

In order to describe the mathematical nature of knitting a stitch, I will first provide a summary of knot theory for context. Knot theory, which emerged in the late 19th century, is a developing field that falls under the larger umbrella of topology.<sup>13</sup> A knot, mathematically speaking, is a closed loop in space that does not “undo” or disappear when manipulated.<sup>14</sup> It is the topological properties of a knot that are of interest to knot theorists.<sup>15</sup>

Topology is the study of geometric properties of a shape that remain unchanged even when the shape is stretched or bent out of its original form.<sup>16</sup> The qualities of a shape are reduced to holes, edges and twists. Through this lens, a donut and a teacup are equivalent in form; they can both be reduced to the quality

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11. Samuel Poincloux, Mokhtar Adda-Bedia, and Frédéric Lechenault, “Geometry and Elasticity of a Knitted Fabric,” *Physical Review X* 8, no. 2 (2018): 021075-1 - 14, doi: 10.1103/PhysRevX.8.021075.

12. Ibid.

13. Daniel Silver, “Knot Theory’s Odd Origins,” *American Scientist* 94, (2006): 158-165.

14. Louis Kauffman, *On Knots*, Princeton University Press, 1987.

15. Ibid.

16. Ibid.

of a single hole, respectively formed by the donut ring and by the handle of the teacup. The topological identity of a shape is only changed by tearing or cutting. These rules apply to the study of a knot. When a knot undergoes any such permissible manipulation it is said to be deformed, but it is still considered to be the same knot or “equivalent.” A flat loop in a plane is called an “unknot” or “trivial knot”; this is the simplest knot. Like any other knot it can be deformed, which can make it difficult to tell whether it is the unknot or some other knot. The basis of much of knot theory is the effort to determine distinctions or equivalencies of knots without spending years untangling pieces of string.<sup>17</sup>

The manipulations that allow for deformation and preserve a knot’s identity are defined in the Theorem of Reidemeister, which states that “two diagrams represent equivalent loops if and only if one diagram can be obtained from the other by a finite sequence of special deformations called Reidemeister moves.”<sup>18</sup>

There are three types of Reidemeister moves. The first type, R1, is a twist and untwist



in either direction. The second, R2, is a move of one loop over or under another. The third, R3, is a movement of a string completely over or under a crossing. The numbering for each type of move indicates how many strands are involved in its movement.<sup>19</sup>

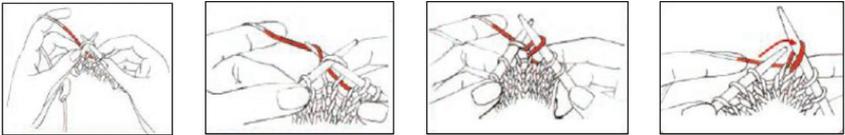
Any knitter is likely familiar with the tragic loss of stitches and knows how easy it is to pull out their work, be it accidentally or on purpose. Without needles, an in-progress knitting can be smoothly pulled out row by row from the active end of the yarn.

17. Ibid.

18. Ibid.

19. Ibid.

This indicates that, before being tied off, the unfinished knitting is essentially an unknot, as the yarn can be entirely untangled. A closer inspection of an individual stitch will demonstrate that the creation of a stitch is simply a single type 2 Reidemeister move and a stretch, manipulations that do not affect the identity of a knot. The figure below<sup>20</sup> shows the steps for knitting a stitch; observe how the active strand is crossed behind the loop and then pulled through.



While this in and of itself should be enough to convince someone that knitting is math, it is also true a knitter does not need to be aware of academic mathematics to do the craft. The following examples and explanations will identify properties of knitting which unavoidably cause the knitter to think mathematically without necessarily being “aware” that is what they are doing.

The majority of knitting is made up of simple arithmetic exercises. The first step of any knitting project is to calculate your gauge, or stitches per inch. This is done to compensate for differences in needle and yarn size between your work and those used in a written pattern, and this conversion is carried out through dimensional analysis. This scaling method uses the property of multiplicative identity, which says any number can be multiplied by 1 without changing its value. For example, a pattern for a 3x6 inch rectangle calling for rows of 24 stitches would have a gauge of 8 stitches per inch. If you knit an inch with only 5 stitches you would either need to use smaller needles to match the pattern’s gauge or adjust the pattern to have 15 stitches per row, thus reflecting your gauge. Computing the gauge of a sample and using it to create measurements for the rest of the

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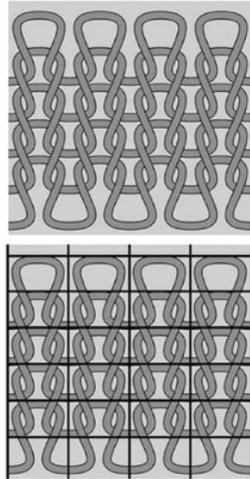
20. Interweave Editorial Staff, “How to Knit Like a Pro: Beginner Knitting Instructions,” *Interweave* (website), 2019.

pattern requires only addition and multiplication, because when we knit, we can only ever have a positive number of stitches and operations are performed using only positive integers (1, 2, 3, ...), which are called the counting numbers or the natural numbers and denoted  $N$ .

### Stitches on a Grid

Thinking of stitches as positive integers should be a first step in any attempt at learning to knit. A typical first knitting project, after learning the basic knit stitch, is to knit a rectangle (call it a scarf) while keeping the same number of stitches on your needles all the way down. Failure to do this shows that dropping a stitch results in a shorter row and the loss of a column. This familiarizes the new knitter with the idea that each stitch represents a number with a placement in both a row and a column. Following this idea, the knitted fabric is

easily translated to a two-dimensional coordinate system in which each stitch is placed inside the boxes of a grid, as in the accompanying figure.<sup>21</sup> In mathematics, two dimensional space is essentially a projection of the physical universe onto a plane, a two-dimensional surface that extends infinitely. Since it encompasses all real numbers it is represented by  $R^2$ ; the dimensions, referred to as length and width, are naturally perpendicular to one another. When describing a coordinate system, length and width take on the



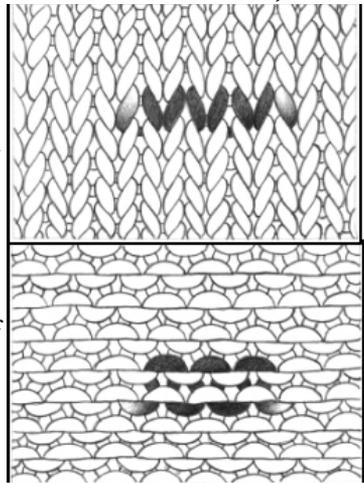
imaging of vertical and horizontal axes with a single unit of length. The intersection of these two axes is called the origin or  $O$ , and thus the two axes become number lines. A Cartesian coordinate system imposed upon a plane works to describe any point or element on the plane using two values, which are called

21. Sarah-Marie Belcastro, “Adventures in Mathematical Knitting,” *American Scientist* 101, no. 2 (2013): 124-133, doi: 10.1511/2013.101.124.

parameters and are conventionally denoted as  $(x,y)$ . Since a plane by definition extends infinitely, the number lines denoted by each axis extend infinitely as well. Under this Cartesian coordinate system, the origin,  $(0,0)$ , is the center point of the number lines and divides the plane into four quadrants. The quadrant where all the coordinate values are positive is generally called the first quadrant. Since stitches are described as positive integers, all work with a knitted plane is done in the first quadrant.

### Differentiating Stitches

There are essentially two stitches in knitting: knit and purl. More complex stitches and patterns are created from combinations or variations of these two. The knit stitch (top of figure), creates a smooth “v” shape, and as described earlier is essentially a slip knot pulled through an existing loop towards the front of the fabric.<sup>22</sup> The purl stitch (bottom of figure), which is the inverse of knit, is a slip knot pulled towards the back of the fabric. It creates a bump or horizontal line. The stitching pattern found on most basic knitted fabric, called stockinette stitch, is created by alternating a knit row with a purl row so that one side of the fabric is smooth knit v’s and its backside is purl bumps. Knit and purl are abbreviated k and p in traditional pattern writing, but 0 and 1 would be equally appropriate signifiers. This simple translation into binary suggests the enormous possibilities of creating codes in knitted fabric.



Many World War One spies were women who would “work code messages into knitting, embroidery, hooked rugs, etc,” and would slide under the radar because

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22. Heather Lodinsky, “A Good Read: Identifying Your Stitches,” *Lionbrand* (blog), April 16, 2013.

they didn't fit the expected profile of a spy.<sup>23</sup> Such is illustrated fictionally in *A Tale of Two Cities*, in which the vengeful Madame Defarge knits an running register of the encoded names and crimes of enemies of the revolution. Madame Defarge encodes these secrets "in her own stitches and her own symbols," implying that no one but herself could ever read it.<sup>24</sup> This reflects the real-life coding practice of representing letters of the alphabet using numbers, the most basic example of which is A=1, B=2, etc. Cryptography methods offer a depth of opportunity for more complex mathematical encryption beyond basic substitution ciphers. Once a message has been encoded, the numbers are placed on a grid which can then be knitted. Since each stitch represents a square in the grid, any technique that creates a single square difference on the background can be used. The visual quality of a stitch can be altered by changing the color or the type of stitch. For example, having a purled stitch on a knit background would allow you to specifically denote that position in the grid.

### **Developing Curvature**

After mastering knit and purl, a knitter will learn to move beyond a simple rectangle. The shape of a knitted fabric can be changed using increases (to add a stitch to a row) or decreases (to remove a stitch). A decrease is a mirror of an increase, so when you flip the fabric upside down, they look identical. They both create curvature in the grid of the fabric, because the overall shape and structure of a knitted object are built out of local stitch creation.<sup>25</sup> For a knitted object that is not flat, any coordinate system imposed on a section of fabric is only accurate for a limited set of stitches. This describes a manifold, a topological

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23. Gordon A. J. Petersen and Marshall McClintock, *A Guide to Codes and Signals* (Racine: Whitman Publishing Company 1942), 58.

24. Charles Dickens, *A Tale of Two Cities* (Project Gutenberg website, 2004), section 2, ch. XV.

25. Sarah-Marie Belcastro. "Adventures in Mathematical Knitting: Rendering Mathematical Surfaces and Objects in Tactile Form Requires Both Time and Creativity," *American Scientist*, vol. 101, no. 2, 2013.

space that has consistent coordinates locally (in a certain limited area) but not necessarily globally (throughout the whole shape). Every point on an  $n$ -dimensional manifold has an area around it that is homeomorphic, or topologically equivalent, to the Euclidean space of dimension  $n$ .<sup>26</sup>

It is helpful to recall that topology is concerned only with the qualities of the space that cannot be altered without tearing, such as holes and connectivity. The dimensional restriction for a manifold is that every patch of the surface must have the same number of coordinate dimensions. Since we are under the assumption that our manifold is describing a knitted object we can continue to operate only in the natural numbers. A simple knitted sweater is an example of a two-dimensional manifold because, if you zoom in, every part of the fabric has a two-dimensional coordinate grid of knitted stitches; the coordinate lines only run up-down and left-right. However, if you added a pocket to the sweater, the place where the pocket connects would have three dimensions, up-down, left-right under the pocket, and left-right over the pocket. So we see after adding the pocket, the sweater is no longer a manifold. This idea of a sweater being consistently two-dimensional might seem odd, as we know that a sweater is in fact three-dimensional; we can wear it! But in this case, the knitting is thought of as a two-dimensional surface, or skin, of a three-dimensional object. The knitting represents the boundary of the three-dimensional object and we think of it as taking up as little space as a piece of paper.

### **Knitted Modeling: Crum Brown's Knitted Surfaces**

This idea of using knitting to represent a two-dimensional surface was first used in mathematics by Scottish chemist and mathematician Alexander Crum Brown (1838-1922). He was recognized primarily for developing a graphical representation of organic molecules that led to the standard notation used today

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26. Ibid.

in organic chemistry.<sup>27</sup> He represented atoms using their atomic symbol written inside a circle; the molecules were then composed of the circular atoms connected by lines, giving a hypothetical molecular structure. The graphic model of a molecule, first published in his 1861 MD Thesis entitled “On the Theory of Chemical Combination,” is valued as a significant contribution to the chemistry world, but it is Crum Brown’s practice of physical modeling that is particularly relevant to the present thesis.<sup>28</sup> To Crum Brown, abstract concepts were more easily understood through three-dimensional models, which he described as “helps to the imagination.”<sup>29</sup> Throughout his career, he created chemical and mathematical models using a variety of mediums, some of which were structurally accurate while others were more abstract.<sup>30</sup> The University of Edinburgh has several of his models on display, including a rock salt molecule composed of balls of yarn connected with steel knitting needles, as well as peculiar triple layer surfaces made of knitted yarn, leather, or paper mache. While not all of these surfaces are necessarily accurate models of his published research, they are valued as essential parts of his explorations in topology.

His paper “On a Case of Interlacing Surfaces,” published in 1855, explores the concept of “locking” which had recently been described by his contemporary and brother-in-law, Peter G. Tait, one of the first mathematicians to study knot theory.<sup>31</sup> Tait’s papers were published by the Transactions of the Royal Society of Edinburgh between 1876 and 1885.<sup>32</sup> In Tait’s *On Knots* (1877) he describes three interlocking rings that form what was later named

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27. David Larder, “Alexander Crum Brown and his Doctoral Thesis of 1861,” *Ambix* 14, no. 2 (1967): 112-132, doi: 10.1179/amb.1967.14.2.112.

28. Ibid.

29. David Dunning, “What Are Models For? Alexander Crum Brown’s Knitted Mathematical Surfaces,” *The Mathematical Intelligencer* 37, no. 2 (2014): 62-70, doi: 10.1007/s00283-014-9480-2.

30. Ibid.

31. Daniel Silver, “Knot Theory’s Odd Origins,” *American Scientist* 94, (2006): 158-165.

32. J O’Connor and E F Robertson, “Peter Guthrie Tait,” School of Mathematics and Statistics, University of St Andrews, Scotland, December 2000.

a Brunnian link, after Herman Brunn, who published an article “Über Verkettung” on knot theory in 1892.<sup>33</sup> These papers laid the groundwork for modern knot theory, a relatively new field of mathematics.<sup>34</sup> Tait had made it his work to catalogue knots, working his way through “the first seven orders of knottiness” (every possible knot created with one to seven crossings) before declaring the prohibitive immensity of this task.<sup>35</sup> Although he hypothesized that there existed some mathematical application to the differences in qualities of knottiness, he had no technique other than his geometric intuition to create these lists.<sup>36</sup> Based off of a theory that interpreted the behavior of floating smoke rings to suggest atoms were knots of swirling vortices in the ether, known as the “vortex atom theory,” Tait postulated that chemical elements must correspond to knots and links.<sup>37</sup> As such, his list of knots was believed to have application in chemistry and physics; it is no wonder then that Crum Brown took an interest in Tait’s knot diagrams.

Crum Brown took the concept of linking and applied it to surfaces. In his “Surfaces” paper he described three sheets perforated with circular holes that interlace in such a way that if any one sheet were eliminated the other two would come apart, analogous to a Brunnian link. Each sheet lies completely above one of the other two, and completely below the other. A link is a collection of knots that are linked together but do not intersect each other, so the arrangement, while not truly constituting knots in a link, followed the essential concept.<sup>38</sup> He went on to suggest different positionings of such a surface. Connecting the ends to form a cylinder can create either one continuous knotted surface (connecting the end of one layer to the opposite end of another) or three distinct surfaces (connecting each layer to its own

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33. Ibid.

34. Daniel Silver, “Knot Theory’s Odd Origins,” *American Scientist* 94, (2006): 158-165.

35. Ibid.

36. Ibid.

37. Ibid.

38. Louis Kauffman, *On Knots*, Princeton University Press, 1987.

opposite end).

To accompany this research, he created models using a unique technique of knitting that produced interpenetrating layers of fabric. The models, which are displayed at the National Museum of Scotland in Edinburgh, are done in three colors, creating designs from Tait's knot diagrams. The fabric is knitted so each color appears in a different section of the design in each layer, which is done by pulling the strands of yarn between the layers. Crum Brown's paper implies he aided the presentation of this paper with physical models to prove his conjectures.<sup>39</sup> While the knitting technique did not perfectly model his surfaces, it should be understood Crum Brown used knitting as a practical form of topological research "not to prove descriptive propositions about his surfaces, but rather to render them perceptible to the senses."<sup>40</sup>

### **Taimina's Crocheted Hyperbolic Plane**

Since much of higher-level math is abstract in nature, it is extremely beneficial to spend time exploring properties of abstract ideas with perceivable faculties. A notable example of such modeling occurred in the 1990s when Daina Taimina, a Latvian mathematician, created the first physical model of a hyperbolic plane using crochet, a medium the mathematics world had not yet thought to try.<sup>41</sup> It is easy to build a three-dimensional physical model for most Euclidean shapes which, by definition, are flat and not curved. Spherical geometry is trickier to model because the surface is curved in on itself and closed, but we have many examples of spheres in our world so it is not unreasonably difficult to figure out a good model. A hyperbolic plane is the geometric opposite of a sphere; it is a surface where the space

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39. As cited in David Dunning, "What Are Models For? Alexander Crum Brown's Knitted Mathematical Surfaces," *The Mathematical Intelligencer* 37, no. 2 (2014): 64, doi: 10.1007/s00283-014-9480-2.

40. Ibid, 66.

41. Daina Taimina and David Henderson (interview by Wertheim, Margaret), "Crocheting the Hyperbolic Plane: An interview with David Henderson and Daina Taimina," *Cabinet*, winter 2004-2005, accessed Sept. 2018.

curves away from itself at every point.<sup>42</sup>

It was after reading a description of a pseudosphere (the hyperbolic equivalent of a cone), which is constructed by adding larger and larger circles to the perimeter, that Taimina knew a hyperbolic plane could be knitted or crocheted simply by increasing the number of stitches in each row.<sup>43</sup> After attempting to knit such a shape, she noted the difficulty presented by the substantial amount of stitches eventually acquired on the knitting needles. Crochet, which works only one stitch at a time, remedied this issue and she gained worldwide notoriety for her unique solution to this modeling problem. Her initial use of knitting and subsequent switch to crochet exemplifies how different fiber crafts have unique properties with useful applications in the area of modeling abstract surfaces. Fiber-related activities are traditionally feminine, so there were not many men with the same skill set as Taimina, demonstrating how the male-dominated mathematics world suffers from its lack of gender inclusivity.

### **Manipulatives**

Many education methods rely on manipulatives to aid in the learning process, especially in the primary and lower elementary grades. The use of manipulatives is intended to “help students learn by allowing them to move from concrete experiences to abstract reasoning,” which is precisely what we observed in the work of Crum Brown.<sup>44</sup> It is important to note that most of the manipulatives used in classrooms today are made of plastic or wood, which serve as models for the male-dominated occupations of building or construction. Genderedness in toys, which are an important aspect of childhood development, clearly displays a cultural bias surrounding this type of hands-on activity.<sup>45</sup> Consumers of Legos, which are comparable to

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42. Ibid.

43. Ibid.

44. Rita Ross and Ray Kurts, “Making Manipulatives Work: A Strategy for Success,” *Arithmetic Teacher*, vol. 20, no. 5, 1993, pp. 254-57.

45. Adele Diamond (interview by K. Tippet), “SoundSeen: In the Room with

manipulatives used for counting and spatial understanding, were reportedly 90% male in 2011.<sup>46</sup> The presence of a gender bias in manipulatives deters young women from mathematics.<sup>47</sup>

Additionally, block-like manipulatives have a fairly limited range of function, and are consequently limited in their ability to demonstrate higher level concepts.<sup>48</sup> Although it would certainly be useful to have aids for higher level concepts, manipulatives are most commonly used in primary and lower elementary classrooms because they lose value after students have developed an understanding of shapes and the counting numbers. The observation that the majority of manipulatives used today are male-oriented or gender neutral, combined with the absence of materials that demonstrate a wide range of concepts, offers educators an opportunity to improve current practices by exploring a wider range of teaching tools – like yarn, for example.

## Conclusion

Fiber crafts can be used as modeling tools to demonstrate a wide spectrum of mathematical concepts, from simple arithmetic to higher-level applications. In lower-level classrooms, stitching can aid counting practice and constructing geometric shapes can help to develop spatial understanding by modeling proportion and scale. At a middle school level, students learn about rate and slope and the Cartesian plane, which can be imposed upon a knitted grid. And so on throughout mathematical education – using the same basic practices, fiber craft takes us all the way to hyperbolic geometry.

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Adele Diamond,” 2009, retrieved from <https://vimeo.com/7708845>.

46. N. Ulaby, “Girls’ Legos are a hit, but why do girls need special Legos?” *NPR Weekend Edition Saturday*, 2013.

47. Mendick, H. (2006). *Masculinities in mathematics*. Maidenhead, Berkshire, England: Open University Press.

48. Melissa Gresalfi and Katherine Chapman, “Recrafting Manipulatives: Toward a Critical Analysis of Gender and Mathematical Practice,” Paper presented at the 9th International Mathematics Education and Society Conference, Volos, Greece, April 2017.

In a 2017 study, KnitLab explored these mathematical education potentials by using GoPro video cameras to observe middle school students knitting.<sup>49</sup> They aimed to show the “overlap of complex mathematics, problem solving, and textile arts like knitting and crochet” could be beneficial to the classroom.<sup>50</sup> The students were of varying math and knitting skill levels, yet all of them demonstrated a development of problem-solving skills over the course of the study. Ventures such as this demonstrate the potential for developing education practices aided by mathematical tools made of yarn. Recognition of the capabilities fiber offers in constructing physical models and illustrating mathematical concepts provides exciting opportunities for these materials to facilitate inclusion and deeper engagement across all levels of mathematical education.



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49. Melissa Gresalfi and Katherine Chapman, “Recrafting Manipulatives: Toward a Critical Analysis of Gender and Mathematical Practice,” Paper presented at the 9th International Mathematics Education and Society Conference, Volos, Greece, April 2017.

50. Ibid.

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**“Untitled” by Cisco McMullin**



## **Part Two**



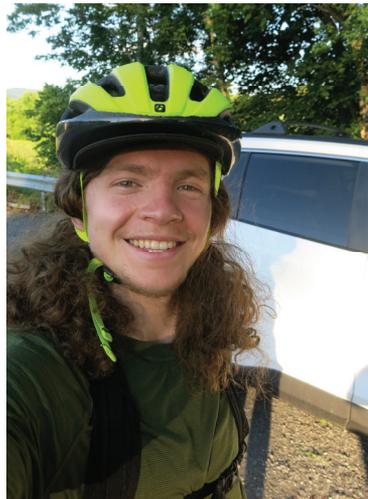
**2021 Pieces**

# Just Transition and a Post-Coal Future for Central Appalachia

**Abstract:** With a dirty past and an unpromising future, one could argue that the coal industry has failed the people of Central Appalachia. From another perspective, the coal industry was never intended to serve the people of Appalachia, yet exploit them and their land while creating cheap energy for the rest of the country. Indeed, it is no coincidence that the coal towns have remained underdeveloped while development in other parts of the country has soared. Employment in the coal mines has plummeted over the last thirty years. Today, the entire Central Appalachian coal industry is in decline, and mountaintop removal mining is leaving a wake of pollution, poverty and irreversible environmental damage. In this thesis I provide a hopeful inquiry into a future beyond coal, where mountain people earn their living by working collaboratively to heal the land, manage their environmental resources, and produce energy sustainably. My research contributes to a growing blueprint of the region's 'just transition,' characterized by a diverse, localized and restorative economy where the wealth produced in Central Appalachia stays there.

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**Griffin Harvey**



## Introduction

Poverty may refer to a lack of wealth, but it doesn't mean that a place and its people aren't rich. What many people consider to be the poorest region in the United States, Central Appalachia is home to a rich culture and some of the most biologically diverse forests in the country. Central Appalachia denotes the central region of the Appalachian mountain range, and consists of primarily rural Southwestern Virginia, Southern West Virginia, Eastern Kentucky, and Northeastern Tennessee. The Appalachian mountains which run through the region comprise one of the oldest mountain ranges in the world and provide a significant cultural and environmental resource for the region.<sup>1</sup> However, the coal underneath these mountains is of high value to the rest of the country, and the development of the region's economy around coal mining has led to the devaluing of its people and land.

Decades of resource and labor exploitation in the Central Appalachian mountains have degraded the social, economic and ecological conditions of the region, leaving both people and the natural environment in a state of distress. Today, coal seams are running thin and regional employment in the coal industry has plummeted.<sup>2</sup> Yet while coal's era may be coming to an end, mountaintop removal mining continues to level ancient mountains and pose threats to the health of people, nature and the global climate. Furthermore, the region's legacy of coal mining has serious implications which still affect the population of the Central Appalachians. Historical absentee land ownership and corporate control over mining has allowed the wealth produced through the extraction and sale of coal to flow out of the communities from which it is extracted. This has resulted in

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1. Glynis Board, "Appalachian Mountains: A Story of Their Own," *West Virginia Public Broadcasting*, June 24, 2019, <https://www.wvpublic.org/news/2019-06-24/appalachian-mountains-a-story-of-their-own>.

2. Eric Bowen et al., "An Overview of Coal and the Economy in Appalachia: Fourth Quarter 2020 Update" (West Virginia University, n.d.), <https://www.arc.gov/wp-content/uploads/2021/04/Coal-and-the-Economy-in-Appalachia-Q4-2020-Update.pdf>.

structural poverty and an undiversified, “one-resource economy” within Central Appalachia.<sup>3</sup>

Almost 20% of Appalachian communities are deemed ‘distressed’ by the Appalachian Regional Commission, and another quarter is ‘at-risk,’ within the poorest 25% of the nation’s population.<sup>4</sup> It is no wonder that authors and activists have referred to the Central Appalachian region as a ‘mineral colony’<sup>5</sup> and ‘sacrifice zone’<sup>6</sup> for decades. These rural communities have been pushed to the fringe of popular society, what’s referred to as the ‘periphery’ in Immanuel Wallerstein’s World Systems Theory. As opposed to the ‘core’ regions where power and wealth is concentrated, the periphery is kept weak and poor and is exploited for the benefit of the core. The people and environment of Central Appalachia have paid the true costs for the energy which fuels homes and cities in the core regions of the nation while experiencing little of the resulting development. Yet today, the industry they have depended on for employment for so long is in a state of decline.

The mechanization of the coal industry in the latter half of the twentieth century caused a steady but drastic decline in mine employment within Central Appalachia, and as coal seams get thinner and cheap, abundant natural gas puts pressure on the coal industry, many coal companies have had to lay off workers or declare bankruptcy.<sup>7</sup> Only a small portion of the region’s

3. Burns, Shirley Stewart, *Bringing Down the Mountains: The Impact of Mountaintop Removal Surface Coal Mining On Southern West Virginia Communities, 1970-2004*, (Morgantown, W.Va.: West Virginia University Press, 2007), 11.

4. Appalachian Regional Commission. “Classifying Economic Distress in Appalachian Counties.” Accessed February 7, 2021. <https://www.arc.gov/classifying-economic-distress-in-appalachian-counties/>.

5. Weller, Rev. Jack. “Appalachia: America’s Mineral Colony.” In *Colonialism in Modern America*, 48. The Appalachian Case. Appalachian State University, 1978. <https://doi.org/10.2307/j.ctt1xp3n1t.8>.

6. Purdy, Jedediah S. “Rape of the Appalachians.” *The American Prospect*, no. 41 (December 1998).

7. Gwynn Guilford, “The 100-Year Capitalist Experiment That Keeps Appalachia Poor, Sick, and Stuck on Coal,” Quartz, accessed February 14, 2021, <https://qz.com/1167671/the-100-year-capitalist-experiment-that-keeps-appalachia-poor-sick-and-stuck-on-coal/>.

population is presently employed by the coal industry, and with disproportionate effects on the ecological and human health of the region, a diversified economy for Central Appalachia has become exceedingly important.

Organizations and entrepreneurs pioneering the possibility of alternative economic opportunities within the region – initiatives centered around forestry, agriculture and the generation of renewable energy – promise economic development and increased local employment while promoting land reclamation and addressing issues including climate change and food insecurity. Collectively, these initiatives comprise a “just transition” away from coal dependence. Transitioning away from coal will entail foundational societal changes on the regional and national scale, and take a tremendous amount of collaborative effort. As such, a just transition within Central Appalachia is neither inevitable nor impossible. It will take decades of work to remediate the land affected by mountaintop removal mining and establish an economy based around sustainable land management.

By understanding the approaches of various organizations working to facilitate a just transition for Central Appalachia, I will contribute to the developing conversation around the challenges and opportunities for growth within the region – a roadmap towards its post-coal future. I examined a diversity of organizations and initiatives involved in the transition, including non-profits, for-profit businesses, corporations, governmental agencies, advocacy groups and grassroots networks. I collected data on current and past economic transition projects through a variety of primary and secondary sources. I identified organizations to examine and individuals to talk to during my preliminary research, while looking specifically for groups that are making on-the-ground efforts to diversify the economy of the Appalachian region. I had the opportunity to speak with a couple of leaders in the region’s just transition to better understand their work and their perspectives. I also drew on information that I gathered from virtual conferences and webinars, televised

interviews, news reports and the websites of organizations and governmental agencies. In an analysis of the data that I've collected, I discuss how various factors, including the scale, approach and profit management strategies of such organizations influence their effectiveness in creating successful economic transition projects. Ultimately, I argue that a broad post-coal transition will require a networked approach, with organizations working together across all sectors of the economy and at every level of society to affect profound social and economic change.

After a review of the existing literature on the history of resource dependence and structural poverty in Central Appalachia, I discuss some of the sustainable development initiatives in the region. My analysis of organizations constituting the region's just transition is divided by sector (forestry, agriculture, renewable energy and creative enterprises) and by approach (specifically, advocacy interest groups and grassroots networks vs. government agencies). Analysis of the aforementioned considerations (profit management strategies, scale and approach) are woven into the discussion of such initiatives. Observation of any of these factors in isolation would be limiting, as it would ignore how organizations which operate at different scales and in different ways interact with each other. Thus, my discussion of the interactions between various groups working to promote a post-coal future brings me back to my central argument that the region's just transition will require a networked approach.

The history of Central Appalachia tells a story of structural poverty, dependence on a waning natural resource, and a degrading landscape. Yet history doesn't determine where Central Appalachia is headed in the future. In the presence of contemporary pressures and changes – to the economy, the climate and the people – the region's future is in limbo. At once concerning and hopeful, the future of Central Appalachia is in the hands of many. Those working to envision and create a socially just, economically diverse and environmentally friendly future for the region are faced with plenty of challenges.

Understanding those challenges, and the strategies that people and organizations are using to advance their goals for a more sustainable future for the region, provides deep insight into the potential for a post-coal transition in Central Appalachia.

### **Structural Poverty, Resource Dependence and Underdevelopment in Central Appalachia**

The poverty experienced within Central Appalachia can be understood through the lens of World Systems Theory. First developed by Immanuel Wallerstein, World Systems Theory divides the world's economy into three zones: the core, the periphery, and the semi-periphery. These three zones exist along a spectrum. Core 'states' are more confined geographic areas where wealth and power (both political and economic) are concentrated. These areas are characterized by their high level of economic development and complexity. Periphery states are characterized by their comparatively low level of economic development. Semi-periphery states are somewhere in between, often having a greater level of industrialization than the periphery.<sup>8</sup>

Peripheral regions are locations where natural resources (such as coal) are extracted, semi-peripheral regions are where natural resources are processed, and core regions are where a majority of the finished products are used and consumed. Peripheral regions are formed and exploited to support the development of industry and society within core states. Thus, their underdevelopment is "not an earlier stage in [their] 'transition' to industrialization" but rather "the result of being involved in the world-economy as a peripheral, raw material producing area."<sup>9</sup> The Central Appalachian region has been purposefully underdeveloped. Referred to as a "mineral colony" and a "sacrifice zone" for decades, the region and its inhabitants have been essentially 'sacrificed' to support economic growth and prosperity in the rest of the country.<sup>10</sup>

8. Burns, *Bringing down the Mountains*, 2.

9. Wallerstein, "The Rise and Future Demise of the World Capitalist System," 392.

10. Weller, "Appalachia," 48.

The impacts of coal mining in Central Appalachia reflect the two contradictions of capitalism, first described by Karl Marx in 1867: overexploitation of labor and over extraction of natural resources.<sup>11</sup> Years before the decline of coal began, Marx predicted that the contradictions which plague capitalism would ultimately lead to the decline of the capitalist system. The poor mining communities of Central Appalachia are no strangers to the impacts of overexploitation. Furthermore, as coal is a nonrenewable resource, any rate of extraction is greater than what can naturally be replenished. As the coal supply has diminished, the practices used to mine coal have become increasingly destructive. Over the past 50 years, mountaintop removal mining (MTR) has become the primary method used to mine coal in Central Appalachia. As a result, the amount of land disturbed by mining has multiplied, even as the rate of coal production (measured in total short tons per year) has dropped from its historic figures.<sup>12</sup>

MTR entails the deforestation and detonation of Appalachian mountaintops which are subsequently pushed aside into the surrounding valleys to expose seams of coal. The coal mined from mountaintops are of higher quality and contain lower levels of sulfur than coal mined at lower elevations, yet these seams of coal are far thinner than those once mined underground.<sup>13</sup> While producing lower yields of coal, MTR results in the loss of topsoil, forests and biodiversity and the permanent disfiguration of natural landforms, destroying important natural and cultural resources. MTR also leads to the burial of headwater streams and pollution of surface and

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11. Karl Marx, *Capital: A Critique of Political Commentary*, ed. Frederick Engels, trans. Samuel Moore and Edward Aveling, vol. 1 (Public Domain Books, 1867).

12. Bowen et al., "An Overview of Coal and the Economy in Appalachia: Fourth Quarter 2020 Update."

13. John McQuaid, "Mining the Mountains," *Smithsonian Magazine*, January 2009, <https://www.smithsonianmag.com/science-nature/mining-the-mountains-130454620/>.

groundwater, which detracts the health of aquatic organisms. It causes the release of air pollutants and greenhouse gases which contribute to global climate change, as well.<sup>14</sup> The list of negative externalities goes on, and MTR causes more than environmental impacts. The practice produces great human costs, too.

Historically, coal mining has been closely associated with miner mortality.<sup>15</sup> The annual rate of deaths associated with work-related accidents has greatly decreased as mining has shifted above ground,<sup>16</sup> although there has recently been a large increase in the number of Central Appalachian coal miners who suffer from black lung disease.<sup>17</sup> This fatal condition is caused by breathing in contaminants released by mining. Still, coal miners represent only a portion of those whose health is directly impacted by mining activities. People living close to mine sites have increased exposure to water- and airborne pollutants released through surface mining, and experience increased rates of cancer, heart, lung and kidney disease as a result.<sup>18</sup> Even babies born in mining areas are significantly more likely to be born with health defects than babies born outside of mining regions.<sup>19</sup>

14. “Mountaintop Removal and Strip Mining,” Kentuckians For The Commonwealth, 2021, <https://www.kftc.org/campaigns/mountaintop-removal-and-strip-mining>.

15. Bradley, “Coal Miners Helped Shape America’s Labor Landscape. Their Industry Is Fading, But That History Is Worth Remembering,” *Time*, October 13, 2020, <https://time.com/5899318/coal-mining-danger-history/>.

16. “Coal Fatalities for 1900 Through 2020” (U.S. Department of Labor - Mine Safety and Health Administration, 2021), <https://arlweb.msha.gov/stats/centurystats/coalstats.asp>.

17. Thomas E. Shriver and Aysha Bodenhamer, “The Enduring Legacy of Black Lung: Environmental Health and Contested Illness in Appalachia,” *Sociology of Health & Illness* 40, no. 8 (2018): 1361–75, <https://doi.org/10.1111/1467-9566.12777>.

18. Michael Hendryx and Benjamin Holland, “Unintended Consequences of the Clean Air Act: Mortality Rates in Appalachian Coal Mining Communities,” *Environmental Science & Policy* 63 (September 1, 2016): 1–6, <https://doi.org/10.1016/j.envsci.2016.04.021>.

19. Melissa M. Ahern et al., “The Association between Mountaintop Mining and Birth Defects among Live Births in Central Appalachia, 1996–2003,” *Environmental Research* 111, no. 6 (August 1, 2011): 838–46, <https://doi.org/10.1016/j.envres.2011.05.019>.

One study which examined mortality in Central Appalachia found that mining areas have experienced an average of 1,200 excess deaths per year since 1990, when amendments to the US Clean Air Act ironically sparked an increase in the practice of MTR in the region. This mortality rate was adjusted for covariates such as smoking, age, and obesity, so it accurately represents the number of deaths correlated with proximity to mines.<sup>20</sup> In addition to MTR, poverty was independently associated with increased mortality rates among Central Appalachians, and the regions with MTR experience consistently elevated rates of poverty.<sup>21</sup> This shows a correlation between the three variables of mining, poverty and mortality.

Where there is more mining, there are increased rates of mortality and poverty, and while mining poses its own health implications, subsequent poverty compounds the issue of mortality. Hendryx found that the value of statistical life lost due to coal mining's impacts was far greater than the revenue generated by the industry, and this statistic didn't even account for the costs of environmental degradation within the region.<sup>22</sup> The only way that the coal industry has remained profitable is through the externalization of these costs; in other words, the passage of these costs onto people and the natural environment.

The people and environment of Central Appalachia have paid the price for the coal mined there, yet little of the profits from the sale of coal even remain in the region. Absentee ownership of land skyrocketed prior to the development of the region's coal industry, which meant that people and corporations from outside of the region controlled the extraction and sale of natural resources, and the resulting flow of wealth.<sup>23</sup> As coal

20. Hendryx and Holland, "Unintended Consequences of the Clean Air Act."

21. Michael Hendryx, "Poverty and Mortality Disparities in Central Appalachia: Mountaintop Mining and Environmental Justice," *Journal of Health Disparities Research and Practice* 4, no. 3 (March 21, 2012), <https://digitalscholarship.unlv.edu/jhdrp/vol4/iss3/6>.

22. Michael Hendryx and Melissa M. Ahern, "Mortality in Appalachian Coal Mining Regions: The Value of Statistical Life Lost," *Public Health Reports* (1974-) 124, no. 4 (2009): 541-50.

23. Weller, "Appalachia," 50.

corporations and absentee landowners often own rights to the minerals underneath the region's surface, they can also determine what happens to the land beneath residents. This has often led to displacement and damage to people's private property, with little repercussions for coal operators. Since those who own the mineral rights live outside of the region, what happens to the surface when coal is mined has no effect on them.<sup>24</sup>

The coal industry is accompanied by a history of corruption and political intervention. Multiple factors, including the vertical integration (conglomeration) of coal corporations, the corporate influence of coal on local governance, and the historical absence of a coal tax in the Central Appalachian states ensured that wealth generated through the production and sale of coal could flow out of the region. As a result, money from coal lined the pockets of the wealthy elite instead of enriching the communities from which the coal was mined. This lack of internal prosperity resulted in chronic underdevelopment within Central Appalachia's mining towns.<sup>25</sup>

The dominance of the highly extractive coal industry in Central Appalachia has prevented alternative industries from developing in the region, even as the coal market falters. While Northern Appalachia industrialized throughout the 20th century, Central Appalachia's economy was honed on coal production and kept non-diverse by the powerful corporations which controlled the region's industrial profile. This made the people of Central Appalachia dependent on the extraction of this resource for their economic survival. The presence of coal can be considered a "resource curse," as dependence on the resource makes the Central Appalachian people financially impotent and vulnerable to shifts within the coal market.<sup>26</sup>

Coal undergoes boom and bust cycles, meaning that production, profits, and employment have historically fluctuated.

24. Weller, "Appalachia," 50.

25. Guilford, "The 100-Year Capitalist Experiment That Keeps Appalachia Poor, Sick, and Stuck on Coal."

26. Guilford, "The 100-Year Capitalist Experiment That Keeps Appalachia Poor, Sick, and Stuck on Coal."

Since the coal boom which resulted from two oil crises in the 1970s, coal production in the region has fallen to an all time low.<sup>27</sup> Contemporarily, rising competition from natural gas has led to massive layoffs of workers in the coal industry. In addition, the mechanization of mining processes and the increasing usage of MTR has led to a significant decline in mine employment in the recent past. In fact, the development of MTR was driven in part by the fact that coal operators don't need to hire as many workers for this method of mining as were previously required to mine coal underground. Today, the coal industry employs fewer than two percent of Central Appalachians, and it's difficult for people living in the region to find a decent source of income outside of the mining sector – Central Appalachia's unemployment rate of 8.6% is 1.7% higher than the national average, and many who are employed work for low wages at big box stores like Walmart.<sup>28</sup>

Due to the politicization of coal mining, a historically 'blue' region of the country has turned "deep red."<sup>29</sup> Many Central Appalachians blamed the Obama administration and the EPA, with their increasing regulation of the coal industry, for the loss of their jobs. Trump's promise to 'bring back coal' brought hope and inspiration to many Central Appalachian people who have a deep and historical cultural affiliation with (and economic dependency on) the coal industry. Yet the coal industry's decline has continued throughout Trump's presidency, with more major coal corporations declaring bankruptcy.<sup>30</sup> The region's role in the US periphery as a supplier of cheap coal energy has nearly expired, and certain academics, activists and entrepreneurs in Appalachia support the notion of a just transition towards a post-

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27. Guilford, "The 100-Year Capitalist Experiment."

28. Guilford, "The 100-Year Capitalist Experiment."

29. Mason Adams, "In Coal Country, a Political Journey from Blue to Deep Red," Virginia Center for Investigative Journalism, November 1, 2020, <https://vcij.org/stories/blue-to-deep-red>.

30. Adams, "In Coal Country, a Political Journey from Blue to Deep Red."

coal future for the region.<sup>31</sup>

MTR has led to surmounting social and environmental consequences as the coal industry attempts to mine the remaining coal in the Appalachian mountains. Costs to human health and the natural environment are far greater than the profit generated through coal mining, and the wealth has led to little economic growth or prosperity within the region. If nothing else, poverty and economic deterioration have elevated the need for a change within the region. Companies and organizations centered around land-reclamation, forestry, agriculture, policy advocacy, social networking and more are working to diversify the Central Appalachian economy and bring stable employment in the wake of the declining coal industry. Below, I will discuss my own research about these initiatives and the conversations I had with leaders of businesses and organizations to demonstrate how they are working to create change, and what they will need to overcome to create a socially just, economically stable and environmentally sustainable future for the region.

### **Just Transition in Central Appalachia**

The surmounting need for a more diverse economy in Central Appalachia is reflected in a growing movement towards a ‘just transition’ for the region. The advocacy interest group Kentuckians for the Commonwealth (KFTC) defines a just transition as an “all-in, inclusive, and place-based process to build economic and political power to shift from an extractive economy to a regenerative one.” A just transition within Central Appalachia implies a shift away from a coal-based economy towards an economy based on regenerative industries that will restore the ecological, social and economic conditions of the region.

In the following pages, I organize my research into four sections: forestry, creative enterprises, agriculture and renewable energy. Initiatives within each of these economic

31. Mark Hand, “Trump’s Empty Pledge to Revive Coal Is Only Punishing Appalachia,” *Think Progress* (blog), February 13, 2019, <https://archive.thinkprogress.org/appalachia-kentucky-west-virginia-just-transition-coal-trump-e5bd-d40065c5/>.

sectors involve some of the components of KFTC's description of a just transition: local inclusion and participation, job creation, workers' rights and safety, social justice, environmental protection and long-term economic stability and growth.<sup>32</sup> One of the most pressing issues to the movement as a whole is the passage of the federal RECLAIM Act, which was passed by the House of Representatives in 2020 but dismissed in Mitch McConnell's senate.

Once passed, the RECLAIM Act would stimulate the release of two billion dollars from the Abandoned Mine Land [AML] Fund, acquired through a tax on coal, to promote economic development and job creation through mine reclamation projects. The AML Fund was first created by the federal Office of Surface Mine Reclamation and Enforcement (OSM), "to provide support for economic revitalization, diversification and development in economically distressed mining communities through the reclamation and restoration of land and water resources adversely affected by coal mining."<sup>33</sup> This act addresses the damage caused by mining prior to the passage of the Surface Mine Control and Reclamation Act (SMCRA) of 1977, before there was any comprehensive federal legislation or governmental body regulating the operation or cleanup of surface mines.

While the SMCRA mandates that mined lands be restored to their approximate original contour and reclaimed to a state of physical stability and ecological health,<sup>34</sup> historical reclamation efforts done in accordance with this act have failed to restore native vegetation or create suitable habitats for animals. Mine reclamation entailed mechanically compacting soils to prevent

32. "Just Transition," Kentuckians For The Commonwealth, 2021, <https://www.kftc.org/campaigns/just-transition>.

33. Matt Cartwright, "H.R.2156 - 116th Congress (2019-2020): Revitalizing the Economy of Coal Communities by Leveraging Local Activities and Investing More Act of 2019," webpage, October 4, 2019, 2019/2020.

34. "30 U.S. Code Chapter 25 - SURFACE MINING CONTROL AND RECLAMATION" (Legal Information Institute), accessed November 27, 2020, <https://www.law.cornell.edu/uscode/text/30/chapter-25>.

erosion and rockslides, and hydroseeding monocultures of non-native grasses to rapidly revegetate the land, thereby preventing erosion. Although erosion control on these sites is essential, compacted soils make it almost impossible for trees to regrow, and this method of reclamation seldom leads to any form of economic development for locals.<sup>35</sup>

### *Forestry*

Patrick Angel, the former leader of the OSM, realized the drawbacks of traditional surface mine reclamation techniques after he visited an experimental reforestation plot on an MTR site in 2002.<sup>36</sup> The plot was planted by students from the University of Kentucky, who seeded a variety of tree species on strip mined land. Through years of research, these students have proven that the forests retain water from rainfall, thereby preventing erosion. Soon after witnessing this successful forestry-based reclamation, Angel helped create the Appalachian Regional Reforestation Initiative (ARRI) to educate mine operators about this technique and to promote reforestation as an approach to reclamation.<sup>37</sup>

During the Obama administration, Angel and his colleague Chris Barton, who oversees the experimental forestry plot, created a proposal for a government-funded, forestry-based conservation core which would employ former miners to plant trees on abandoned mine lands and retired MTR sites. When Van Jones, a friend of Angel and advisor to Obama, resigned, they lost their connection to the president and had to rethink their approach. They brought the proposal to the Appalachian Regional Commission (ARC), an economic development agency of the federal government, instead, and the ARC provided them with

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35. "Reclamation with Trees: The 'Dark Ages' and the 'Renaissance,'" *International Journal of Mining, Reclamation and Environment* 23, no. 1 (March 2009): 1-3, <https://doi.org/10.1080/17480930902734053>.

36. Gabriel Popkin, "Kentucky Was Devastated for Decades by Mountaintop Removal. Now Scientists Have Figured out a Way to Undo the Damage — One Tree at a Time," *Washington Post*, February 13, 2020, <https://www.washingtonpost.com/graphics/2020/lifestyle/magazine/appalachia-kentucky-reforestation/>.

37. Popkin, "The Green Miles."

a small grant. This grant funded the creation of the non-profit Green Forests Work, which became one of the first reclamation-based economic transition projects in the region in 2009.<sup>38</sup>

Green Forests Work (GFW) is a KY-based non-profit working to restore the environment and bolster the economy of Central Appalachia through reforestation projects. GFW restores AMLs and other degraded landscapes using the ‘deep ripping’ technique first developed and implemented on Barton’s experimental plot. During this process, contract workers bulldoze sites to remove non-native and invasive vegetation and score the soil to prepare it for new plantings. Afterwards, volunteers and/or paid workers plant a variety of native tree saplings on the ripped land. According to Michael French, the lead director of GFW, the organization has planted over 3.1 million trees across 5,000 acres of land since 2009, and seeks to plant another 1 million trees on 1,400 acres in 2021.<sup>39</sup> They’ve also brought in over a million dollars into the local economy and engaged Appalachian communities in the process.<sup>40</sup>

GFW is funded through a mix of federal grants and contracts, corporate sponsorships, public and philanthropic donations and partnerships with organizations including the Arbor Day Foundation. Their 501c3 (non-profit) status has allowed them to scale up since their start as an initiative in 2009, as it allows them to directly solicit donations and apply for grants. In turn, this money is used to hire workers from the Appalachian region, including professional tree planters, construction workers and former coal miners, to prepare the land and plant trees. The funds are also used to purchase local materials such as tree saplings. Secondary industries including retail, hospitality, restaurant and transportation businesses also benefit when laborers are brought in from other parts of the region to plant trees. Volunteers comprise about 20% of GFW’s labor force for planting trees. Volunteer groups have included Boy Scouts and Girl Scouts, public school groups and college students, corporate

38. Popkin, “The Green Miles.”

39. Michael French, personal communication.

40. Popkin, “The Green Miles.”

sponsors, environmental groups and more.<sup>41</sup>

As a result of volunteers' participation in tree plantings, GFW has had the opportunity to educate the public about the importance of forests and current threats to the wellbeing of the natural environment. However, the organization is young and they lack the brand recognition of other environmental groups, making it difficult to raise awareness on a broader scale. French believes that the organization will require more exposure and funding to continue scaling up their operation and expand the social, environmental and economic impacts of their work. More funding from private investors and federal grant programs (like the RECLAIM Act) would allow GFW to undertake more tree plantings as well as hire and train permanent employees to monitor and maintain reforestation sites year round.<sup>42</sup>

According to French, GFW has two major advantages. The organization's approach to promoting a just transition is based around a renewable and sustainable resource: trees. Unlike coal, trees will replenish naturally and in a short period of time. If stewarded correctly, they will provide a consistent and reliable source of income for landowners who choose to capitalize on the timber and non-timber forest products that come from reforestation. In conversation, French remarked on how he hopes that as Central Appalachia transitions away from coal, the region will transition back to its historic economy, based around forestry and agriculture. This transition is essentially what GFW and other reclamation organizations are attempting to create.<sup>43</sup>

French emphasized how such a transition will require a "coalition of organizations with overlapping missions, working in cooperation" to instill change. This correlates with the second advantage of GFW's approach – that they work collaboratively with other organizations. GFW has "always been... willing to share resources and leverage funding, and help other organizations achieve their goals."<sup>44</sup> GFW works with a diverse

41. French, personal communication.

42. French, personal communication.

43. French, personal communication.

44. French, personal communication.

array of partners in the non-profit, corporate and governmental sectors, including the Appalachian Conservation Corps, US Forest Service, ARRI and even Komatsu.

Komatsu is a Japanese multinational corporation (MNC) which produces construction, mining and forestry equipment. GFW's partnership with Komatsu is aiding the MNC in achieving their corporate sustainability goals while bringing in funding for GFW's projects. This funding is supporting GFW's mission to "spread proper reclamation efforts on a [regional, and even] global scale."<sup>45</sup> This example demonstrates how collaboration between different types of organizations can be mutually beneficial, and more specifically how reforestation projects benefit from grassroots participation and ownership *and* the support of large, for-profit entities.

### *Creative Enterprises*

The Coalfield Development Corporation (CDC) is a pertinent example of a local nonprofit that's working to promote the growth of for-profit businesses within Central Appalachia. Since 2011, the WV-based organization has been training and hiring a local workforce while supporting the development of creative enterprises. Students who go through the CDC's employee development program acquire several professional certifications in addition to earning a degree and gaining traction within a career.

The CDC owns or co-owns multiple employment-based social enterprises that are "designed to diversify the regional economy to be less dependent on coal."<sup>46</sup> These enterprises often hire graduates from the CDC's training program, and provide revenue which allows the organization to be "less grant-dependent and more financially sustainable."<sup>47</sup> As opposed to

45. Dr. Chris Barton, cited in "Komatsu Launches Reforestation Partnership with Green Forests Work" (Komatsu, April 22, 2019), <https://www.komatsu-america.com/our-company/press-releases/2019-04-22-green-forests-work>.

46. Brandon Dennison, "10 Years," Change in the Coalfields: A Podcast by Coalfield Development, accessed May 3, 2021, [https://coalfield-development.org/media/..](https://coalfield-development.org/media/)

47. Dennison, "10 Years."

nonprofits like GFW that are dependent on grants for their funding, the CDC remains largely self-sufficient due to the revenue from their for-profit social enterprises. This funding goes to the CDC's economic development programs and SEED fund.

The CDC's Social Enterprise and Economic Diversification (SEED) Fund "makes equity investments in social entrepreneurs with viable ideas... to hire local people facing barriers to employment."<sup>48</sup> Through the SEED Fund, the CDC is distributing wealth to new and creative businesses and thus to people in need of employment. The CDC's Workforce Readiness and Professional Success (WRAPS) program is dedicated to partnering with "community-based organizations willing to implement [their] job training and personal development curriculum for local people facing barriers to employment." Through the WRAPS program, the CDC's employee development curriculum has been implemented by several other local organizations. Their triple bottom line – people, planet, profit – emphasizes social and ecological well-being first, while still recognizing the importance of generating revenue.

### *Agriculture*

Subsistence and commercial agriculture have been a part of Appalachia's economy for generations, and it has its own role in the region's post-coal transition. One company in particular is determined to harness the region's agricultural potential: AppHarvest is a public, for-profit agricultural company that seeks to "feed the future, from the heart of Appalachia" while turning the economically-distressed Eastern Kentucky into a major regional hub for fruit and vegetable production.<sup>49</sup> Like Reclaim Appalachia, AppHarvest planned to farm on top of MTR sites, but the process proved to be "too costly."<sup>50</sup> Nevertheless, the

48. "Meet Our SEED Partners," Coalfield Development, 2020, <https://coal-field-development.org/meet-our-seed-partners/>.

49. AppHarvest. "AppHarvest," 2021. <https://www.appharvest.com/>.

50. Leigh Kamping, "The Indoor Farmer Who Wants to Remake Appalachia's Agriculture," *The Toronto Star*, August 15, 2019, <https://search-proquest-com.proxy191.nclive.org/docview/2273334785?pq-origsite=summon>.

company is building three massive 40 to 60-acre greenhouses in the Eastern KY, where tomatoes and other crops will be grown. The agricultural model used by AppHarvest allows for crops to be grown year round and without the use of pesticides, which means that it pollutes less and is more resilient to varied environmental conditions resulting from climate change than conventional, commercial agricultural practices.

AppHarvest's large scale confers advantages over small-scale food production models because they are able to produce fruits and vegetables at scale and market directly to grocers and supermarkets. They are also able to cut down their up-front capital costs, which pose barriers to entry for small farmers. While they use organic farming methods, AppHarvest refrained from becoming certified organic, as to reduce the amount of competition they put on small organic farmers in the region. Their goal is to bolster the local economy and outcompete commercial farms which rely heavily on pesticide use.<sup>51</sup>

Smaller-scale agricultural organizations are also doing their part to turn Appalachia into a regional hub for food-production. Generally grassroots, these organizations consist of alliances, cooperatives and collectives that are working to support a network of small farmers in the region. Appalachian Harvest (not to be mistaken with AppHarvest) is a rural food hub owned by a larger non-profit, Appalachian Sustainable Development. The group has been helping bolster small farms, providing a multitude of services from training farmers for GAP (Good Agricultural Practices) certification and organic certification to providing technical support and farm inspections. The organization also aggregates, stores, markets and distributes small farmers' produce, selling to large buyers such as supermarkets or to secondary markets when the produce is imperfect. These services help reduce the barriers that prevent small farmers from selling their produce and making a living from organic agriculture.

Similar organizations such as Community Farm Alliance

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51. AppHarvest, *23rd Annual ICR Conference*.

and the Turnrow Appalachian Farm Collective also provide marketing and distribution services to help small farmers sell their produce. This is referred to as value chain development because value is added to the produce through marketing. Through developing a value chain, these organizations are expanding and strengthening the region's agricultural network, helping form buyer-supplier relationships and increasing the exchange of products and money between farmers and consumers. Yet to do work in forming a regional agricultural network, these nonprofit organizations need sources of money.

The United States Department of Agriculture (USDA) promotes value chain development through their Local Food Promotion Program (LFPP). The federal program “funds projects that develop, coordinate and expand local and regional food business enterprises” like the previously mentioned cooperatives and collectives.<sup>52</sup> They provide the funding that makes it possible for nonprofit organizations to do value chain development work. There are also non-governmental organizations doing similar work.

Farm Aid, a non-profit, raises money for farmers and organizations through their annual music festival and by soliciting donations, and they provide financial aid in the form of grants. The Natural Capital Investment Fund (NCIF) has a similar goal to Farm Aid, but they acquire funds from a different base of donors, including major banks, corporations and governmental agencies. These organizations are essentially funneling money from outside sources into Central Appalachian businesses, thereby promoting the development of value chains and a local economy. This model demonstrates how economic development in the agricultural sector of Central Appalachia benefits from a network of groups and individuals who donate, transfer and appropriate development money.

### *Renewable Energy*

The discussion of Central Appalachia's post-coal  
52. “Local Food Promotion Program | Agricultural Marketing Service,” accessed April 9, 2021, <https://www.ams.usda.gov/services/grants/lfpp>.

transition would be incomplete without considering the role of renewable energy production. Gaps left in the economy by the decline of the coal industry are necessitating both diversified energy sources and economic opportunities. While the people of Central Appalachia can no longer depend on coal for employment, the rest of the nation can no longer depend on the region for cheap and abundant coal energy. For this reason, serious consideration must be given to the possibility of expanding the region's renewable energy profile. AMLs could potentially provide arable land for biofuel production, yet wind and solar energy farms may be the most scalable solutions. AMLs are often suitable and opportune locations for solar and wind farms, as MTR leaves flat and open landscapes which are ideal for this type of development. In addition, the existing energy infrastructure (grid) built for coal would reduce the up-front costs to implement solar and wind projects in the region.

Renewable energy development has the potential to produce an array of environmental and economic benefits for the region. The creation of solar and wind farms necessitates that AMLs be remediated, which means that renewable energy projects would leverage the funding necessary to do reclamation work and prevent any further water contamination from those sites. Transitioning away from coal energy and towards renewable energy would address the specific impacts of the coal industry on human health and the natural environment of Central Appalachia, as it would curtail the environmental degradation caused by MTR and prevent continued release of pollutants into the region's air and water. In general, a greater reliance on renewable energy sources would result in reduced fossil fuel usage and thus reduced emissions on a local, regional, national and global scale. The economic benefits of renewable energy development include local job creation, increased revenue,

economic development and energy security.<sup>53</sup>

A major challenge and critique of solar and wind farming is that they produce energy intermittently (meaning they don't constantly produce energy). The Tennessee Valley Authority (TVA) is working to address this issue at the Buffalo Mountain Wind Park in Tennessee by creating facilities to store the energy produced by wind turbines. Built in 2000, Buffalo Mountain was the first commercial wind farm in the Southeast. Yet for years, locals voiced their concerns about the construction of Buffalo Mountain wind park and others in the region. This is because wind turbines create auditory and visual disturbances. Besides bothering residents, some people fear that this would lessen their property values and/or diminish local revenue from tourism.<sup>54</sup> Wind farming has also received criticism for its potential impact on wildlife, although this must be viewed comparatively to its primary alternative, MTR mining.

Another challenge to the development of wind and solar farms in the region are the complicated permitting procedures<sup>55</sup> and lack of legal incentives. Federal policies and programs including tax incentives and grant programs are key for stimulating wind and solar development. These policies have been essential in driving down the cost of solar and wind energy projects and making them more competitive against fossil fuels.<sup>56</sup>

Multiple stakeholders are intertwined in the process of developing wind and solar farms on AMLs, including government regulators, landowners, mining companies,

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53. "A Breath of Fresh Air for America's Abandoned Mine Lands: Alternative Energy Provides a Second Wind," March 2012, <https://semspub.epa.gov/work/HQ/176038.pdf>; "Shining Light on a Bright Opportunity: Developing Solar Energy on Abandoned Mine Lands," December 2011, <https://semspub.epa.gov/work/11/176032.pdf>.

54. Jenna Portnoy, "After Coal, Appalachia to Wind Farm Proposal: 'It Is Insulting, Really,'" The Washington Post, August 20, 2015, <https://search-proquest-com.proxy191.nclive.org/docview/1705669354?pq-origsite=summon>.

55. "A Breath of Fresh Air"; "Shining Light on a Bright Opportunity."

56. Alan A. Campoli et al., "Adaptive Reuse of Mined Lands for Solar Energy," *Mining Engineering*; Littleton 71, no. 6 (June 2019): 18,20,22,24,26-31.

corporations and energy utility companies.<sup>57</sup> This is exemplified in the proposal of a solar farm on Bent Mountain, Kentucky, the development of which will be carried out by a trio of companies: Toyota, EDF Renewable Energy and Edelen Strategic Ventures. In addition, development on Bent Mountain is dependent on the site's reclamation, which will be completed by Kentucky Fuel, a coal company, and overseen by Kentucky state government regulators.<sup>58</sup>

Nonprofit organizations have also been major contributors to the development of Central Appalachia's renewable energy industry. For example, the Nature Conservancy is working with local organizations such as the Coalfield Development Corporation and Downstream Strategies, a WV-based private consulting firm, to identify, map, and purchase AMLs which are suitable for the development of solar and wind farms, and raise funds for development. Amidst the network of various stakeholders involved in renewable energy development throughout Central Appalachia, the importance of involving local workforces and landowners cannot be overlooked.

## **Organizational Approaches to a Just Transition for Central Appalachia**

### *Advocacy Interest Groups*

There are dozens, if not hundreds of grassroots and community-based organizations working to facilitate a just transition within Central Appalachia; organizations which focus on economic development, social justice, energy democracy and environmental protection. Advocacy interest groups play a particularly important role in the region's just transition due to their ability to combine, organize and lift up the voices of local

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57. Joey James et al., "A Roadmap for Solar on Mine Lands in West Virginia: Emerging Opportunity to Grow the West Virginia Economy, Attract New Employers, Increase Investment and Create Jobs," February 7, 2020, <https://www.nature.org/content/dam/tnc/nature/en/documents/WV-roadmap-solar-on-minelands.pdf>.

58. Will Wright, "Toyota Provides 'final Step' for Big Solar Farm," *Cincinnati Enquirer*, March 21, 2019, sec. News.

people advocating for change, as well as raise funds, network people and businesses, and coordinate broad-scale campaigns to promote a post coal future for the region. Two primary interest groups, Appalachian Voices and Kentuckians for the Commonwealth (KFTC), are useful to examine because of their influential roles in the region's just transition.

KFTC is made up of 14 chapters from around KY, and the nonprofit has the distinct advantage of operating on both the community and state levels to build momentum for their campaigns. KFTC's platform includes bolstering voting rights and racial and economic justice, transitioning to clean energy and protecting communities from the impacts of coal mining. The organization's approach is both social and political in its nature and incorporates "strategic communications, voter empowerment, [and] non-violent direct action," (eg. lobbying and protesting), along with "grassroots fundraising, alliance building and litigation."<sup>59</sup> KFTC directly interfaces with the government in their approach to promoting a just transition for the region.

As an organization, KFTC recognizes the intersection between racial and economic injustice and environmental issues. By working to restore voting rights to all Kentuckians, they seek to improve the function of the state's democracy and increase representation for those who have been systematically oppressed, disenfranchised and impacted by poverty and environmental degradation. The organization actively opposes MTR and its impacts on people and the natural environment by organizing/ conducting citizen science (eg. testing water sources impacted by acid mine drainage), conducting education and outreach about MTR, publishing informational media and holding public forums, organizing protests and even litigating against coal companies in court to hold them accountable for their pollution and legal violations. KFTC's goal is "to stop and punish illegal mining practices that endanger people and the... environment."<sup>60</sup>

59. "Our Approach," Kentuckians For The Commonwealth, 2021, <https://kftc.org/about-us/our-approach>.

60. "Litigation," Kentuckians For The Commonwealth, 2021, <https://kftc.org/issues/litigation>.

Appalachian Voices is another advocacy interest group, similar in its goals and mission to KFTC, which focuses specifically on fighting against the expansion of coal mining and natural gas in Central Appalachia and on campaigning for the expansion of the region's renewable energy industry. The organization's mission highlights the centrality of energy democracy to economic, environmental and racial justice, emphasizing the role of renewable energy in the region's just transition. Through community organizing, outreach, policy advocacy, litigation and funds acquisitions, the nonprofit is working to protect people from the negative impacts of fossil fuel industries and to increase local access to renewable energy resources.

Appalachian Voices has been organizing protests against the construction of the Mountain Valley natural gas pipeline and has litigated against companies involved in the project in court. The group's direct action has led to a federal hold on the pipeline's permit and put a temporary stop to its construction. Appalachian Voices is also challenging corruption in the energy sector and campaigning for democratic reform in government agencies including the Tennessee Valley Authority (TVA). The organization has teamed up with several nonprofits to plan and fund new solar development projects on AMLs in seven counties in Southwestern Virginia, with the goal of revitalizing the local economy and bolstering people's access to energy from solar.

As their name suggests, Appalachian Voices represents a collective voice of the people of Central Appalachia. Their newspaper, *The Appalachian Voice*, provides "well-researched journalistic news coverage" of environmental issues which impact the region<sup>61</sup> and also celebrates the region's rich cultural and natural landscape. Appalachian Voices' sister webpage, "ILoveMountains.org," is where members upload photos, videos and maps produced through Geographic Information Systems (GIS) tracking the extent of land degradation caused by MTR.

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61. "About The Voice," *The Appalachian Voice* (blog), 2021, <https://appvoices.org/thevoice/about/>.

This page is used to educate the public about the environmental and social externalities of MTR and expose fraudulent and improper mine reclamation practices. ILoveMountains.org has become a platform for several member organizations of the Alliance For Appalachia.<sup>62</sup>

### *Grassroots Networks vs. Government Agencies*

The Alliance For Appalachia is one of several grassroots networks working to facilitate a just transition in Central Appalachia. Others include the Central Appalachian Network (CAN) and the Reclaiming Appalachia Coalition. These coalitions are composed of multiple nonprofit and for profit organizations collaborating to advance a regional transition. The Alliance For Appalachia is composed of 15 different organizations, including Appalachian Voices and KFTC, which each have their own role in promoting a just and sustainable future for the region. The CAN is composed of groups including the Coalfield Development Corporation, Appalachian Sustainable Development and the NCIF. Through diverse partnerships, these organizations are working to orchestrate and advance systemic change, addressing social and environmental issues while promoting economic development and mutual aid. Together, these grassroots networks form a network of networks; a regional coalition composed of dozens of organizations, linked together in a combined effort to restore the environment and economy of Central Appalachia.

Grassroots networks are especially important in the way they interface with state and federal governments, facilitating collaboration and promoting democratic reform. According to members of the Alliance for Appalachia, “existing governmental development structures are deeply fragmented” which makes it difficult “to build an adequate support structure for economic transition projects” and provides an “entry point for corporate

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62. “About ILoveMountains.Org,” ILoveMountains.Org (blog), accessed April 16, 2021, <https://ilovemountains.org/about>.

power.”<sup>63</sup> Through collaborative projects and efforts, these powerful grassroots networks aim to fill the gaps within governmental development structures to support a regional economic transition and prevent corporate powers from using those gaps as an opportunity to maintain their hegemony.

The Alliance for Appalachia and its member organizations have campaigned for the passage of the RECLAIM Act for over a decade to stimulate the release and appropriation of money from the AML fund for mineland restoration projects throughout Central Appalachia. They have also campaigned for reform within the Appalachian Regional Commission (ARC), a federal economic agency which appropriates funds from Congress to invest in education, job creation and infrastructure development. Reformation ensures that money from the ARC goes “to benefit local organizations, businesses, and communities rather than continuing to support existing infrastructure expansion projects.”<sup>64</sup>

Top-down development sometimes fails to meet the actual needs of communities, and grassroots organizations can work to direct the flow of money, aid and resources to those who need it the most. Brandon Dennison, founder of the Coalfield Development Corporation, emphasizes that “it is a strong collaboration from the grassroots to the highest levels of leadership that can truly advance a land restoration economy in Central Appalachia.”<sup>65</sup>

## Conclusion

Home to vibrant social and ecological communities, Central Appalachia is a resource rich but economically poor region of the eastern United States which has long existed

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63. Betsy Taylor et al., “Economic Transition in Central Appalachia: Knowledge/Power Mapping for Bottom-up Policy,” *Practicing Anthropology* 36, no. 4 (2014): 13–18.

64. Taylor et al., “Economic Transition in Central Appalachia.”

65. “Many Voices, Many Solutions: Innovative Mine Reclamation in Central Appalachia,” November 13, 2018, [https://appvoices.org/resources/AML-RAC/AML\\_RAC\\_report\\_Many\\_Voices\\_Many\\_Solutions-11-13-18-lo-res.pdf](https://appvoices.org/resources/AML-RAC/AML_RAC_report_Many_Voices_Many_Solutions-11-13-18-lo-res.pdf), 51.

at the periphery of mainstream society. Having been denied the opportunity to industrialize beyond coal mining, the region's economy has been kept depressed and non-diverse by corporations which own the land and control the extraction and sale of natural resources. As the region's coal mining industry becomes increasingly destructive, decreasingly productive, and hires fewer Appalachian miners, the need for a just, post-coal transition for the region has become ever more prevalent. Transitioning away from coal mining and towards a restorative, land-based economy will entail profound social and economic change in the region, including the diversification of the region's industrial profile and reform of the region's energy sector.

Organizations working to promote a just transition within Central Appalachia operate at a variety of scales, with differing profit management strategies and diverse approaches. A mix of small-scale, commercial, local, regional, and national actors and organizations intersect in this combined effort to diversify the region's economy. Economic revitalization and social justice is advanced through the actions of both nonprofit and for-profit organizations and through a collaboration between grassroots and top-down actors. Differing individual approaches to a just transition have varied advantages and disadvantages, yet any one approach in isolation wouldn't be sufficient or successful at affecting profound change. A just transition for the region is neither inevitable nor impossible, but it will require a networked approach, with organizations working at a variety of levels and within multiple sectors of the economy to create a future beyond coal.

Future research should delve into the discussion of Central Appalachia as a microcosm of global environmental and social issues and transitions which are occurring around the world. Central Appalachia shares parallels with several other coal mining regions across the planet, including Wales, United Kingdom, which has already transitioned away from coal mining, and New South Wales, Australia, which is at a similar stage in their post-coal transition. Many regions will follow in

the footsteps of those who have already transitioned from coal, and Central Appalachia can “share [its] toolbox” to aid other regions who are making the shift.<sup>66</sup> Analyzing these international interactions would help us to understand what a just transition will look like on a global scale, and provide an opportunity to extrapolate on the argument for a networked approach.



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66. Michael French, Personal Communication.

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**“Or The Darkness Thereof” by Emily Chebli**



# A Comparative Analysis of Benthic Macroinvertebrate Populations Before and After Stream Restoration in Two Warren Wilson College Streams

**Abstract:** Several Warren Wilson College streams were restored as a result of stream mitigation banking. The streams had become channelized over time as a result of intensive agriculture in the area. The streams' geomorphology was reconstructed to increase habitat heterogeneity and restore flow patterns to a more natural state. Two particular streams were studied both one year prior and one year following restoration. In these two streams, benthic macroinvertebrate communities were studied in order to compare taxon richness and abundance of pollutant intolerant insects before and after restoration. After restoration, both streams showed a decrease in EPTs (Orders: Ephemeroptera, Plecoptera, and Trichoptera) in the downstream sites, suggesting that strides have not been made in respect to increased biodiversity or abundance, despite the successful restoration of habitat heterogeneity throughout the new channels. The author suggests continued research in order to determine project success as well as additional management strategies for future endeavors.

## Kaitlyn Zinnecker



Growing up on the shores of Lake Superior, Kaitlyn Zinnecker (she/her) has always had an innate appreciation for lakes, streams, and their inhabitants. This love for all things aquatic was the foundation for her studies at Warren Wilson College and ultimately informed the subject for this thesis. Under the guidance of Professor Mark Brenner, Zinnecker graduated in 2021 with double honors in Biology and Environmental Studies. In the future, Zinnecker hopes to continue her studies and is currently seeking out graduate school positions in the field of Aquatic Ecology.

## Introduction

River restoration and stream mitigation are gaining increasing attention in the world of habitat conservation and wildlife management (Palmer et al., 2007). Stream mitigation banking is one of the sources for the rising numbers of restorative projects that are being seen across the country, especially in the Southeast (Lave et al., 2008). Stream mitigation banking allows developers to offset the ecological damages to waterways caused by their construction (i.e. roads, bridges) by purchasing credits that are used to restore streams and wetlands elsewhere so there is no net loss to the environment (Lave et al., 2008).

Warren Wilson College in Buncombe County, NC, is one of the places in the country where this type of exchange is taking place. Warren Wilson College currently operates a 300 acre farm and the institution itself boasts a rich history of agriculture, with the school forming in 1894 as the Asheville Farm School. Agriculture is one of the primary causes for stream degradation and is often one of the main contributors to channelization of streams throughout the world (Allan, 2004, Riseng et al., 2011, Vörösmarty et al., 2010). Channelization causes problems for many streams especially during heavy rains, because sediment and water flow very rapidly, causing erosion and loss of substrate, plant matter, and animals. In addition to the increased ecological cost of flooding, channelization decreases habitat heterogeneity, a measure of habitat diversity in ecosystems. A decrease in habitat heterogeneity is thought to result in decreased diversity of microhabitats and as a result a decrease in biodiversity (Lepori et al., 2005). Due to intensive farming practices in the past, many of the streams on Warren Wilson campus have become channelized.

When contractors unchannelize a stream in an attempt to restore it to its natural state, they are altering what's referred to as the geomorphology of the stream. Stream geomorphology focuses on the physical aspects of the stream and includes assessment of the stream's curvature, elevation differences, flow patterns, and geology. Geomorphological restoration can produce an array

of favorable outcomes such as lessening the impact of erosion and maximizing habitat diversity (Tullos et al., 2009). By adding boulders and small stones, additional habitat is created resulting in an increase in ecological surface area within restored streams (Spänhoff & Arle, 2007). Stream restoration projects primarily focus on the geomorphology of streams, because it is typically the easiest to assess and fix, despite scientists stating how important water quality is to the survival of many aquatic species (Jahnig et al., 2010; Sundermann et al., 2011). Restoring the geomorphology of a stream is a step in the right direction but ultimately a healthy ecosystem will be limited by poor water quality not its physical features (see Figure 1.) (Langford et al., 2009; Robinson et al., 2014).

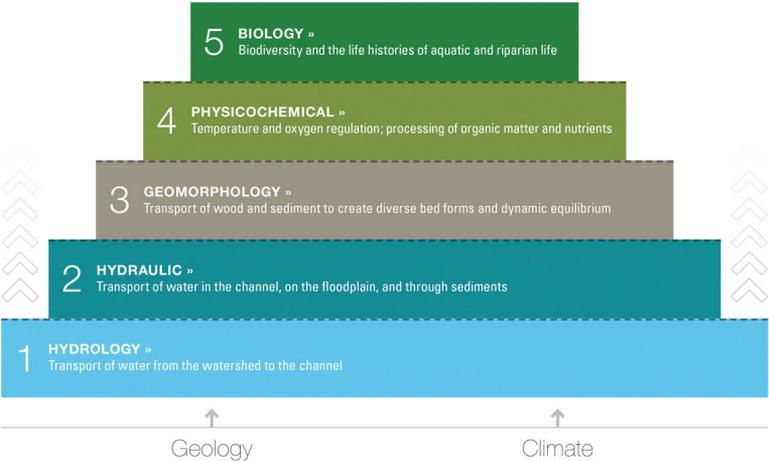


Figure 1. The Stream Restoration Pyramid, also known as the Functional Lift Pyramid, shows the physical, chemical, and biological components of a stream, each step being dependent on the steps below it. US Fish and Wildlife Service, 2012.

The logic behind restoring a stream’s geomorphology stems from niche theory, which theorizes that increased habitat heterogeneity should yield increased biodiversity as a variety of habitat niches would allow many different species the ability to coexist with one another. Much of the research that supports

this however comes from terrestrial ecosystem studies and the impacts of increased habitat heterogeneity in aquatic systems are poorly understood with the results of channel restoration, bank enhancement, and addition of habitat for the most part, inconclusive (Lepori et al., 2005).

Despite geomorphologic restoration occurring throughout the country, many restoration efforts are understudied or possess poor study designs. The majority of projects do not include data from prior to restoration which limits the conclusions that can be made. Even when studies do include both pre- and post-restoration surveys, a significant portion of them are only “snapshot” looks at the invertebrate communities. “Snapshot” study designs, which typically only monitor once before restoration and again several years after construction, give limited insight into the effects of restoration. The importance of good study design prior to restoration as well as long-term research efforts cannot be understated (Louhi et al., 2011).

BACI experiments are one of the best examples for studying restoration efforts due to their simple but effective design. BACI, which stands for Before After Control Impact is an acronym that implies the occurrence of surveying efforts both before and after restoration, as well as in different sites. The different sites consist of the control sites, which are not altered with respect to stream mitigation and provide a template for successful restoration, as well as impact sites, that have been altered with respect to stream mitigation. These impact sites will give us the most insight in how restoration has fared for the macroinvertebrate communities. For this project, I participated in a BACI experiment in order to determine how populations of pollutant sensitive invertebrates have changed with respect to restoration.

Several exhaustive studies with BACI experimental designs or designs similarly rigorous, have been done around the world. Despite their comprehensive study designs however, it is still unclear whether morphological stream restoration

results in increased biodiversity, with most studies yielding less than promising results (Albertson et al., 2011, Lepori et al., 2005, Louhi et al., 2011). These studies show that the effects on benthic macroinvertebrate communities are incredibly varied with the aftermath of restoration efforts becoming seemingly unpredictable (Albertson et al., 2011, Lepori et al., 2005, Louhi et al., 2011). Some long-term studies have shown rapid increases in macroinvertebrate abundance following initial plummets after reconstruction but these same studies found that diversity did not increase as a function of time (Spänhoff & Arle, 2007). Further, Palmer et al. found upon examining 78 restored streams, only 2 of them demonstrated an increase in macroinvertebrate diversity, indicating there was absolutely no evidence of a correlation between habitat heterogeneity and invertebrate diversity, further suggesting that restoring stream geomorphology should not always be the primary goal for mitigation projects (2010). Not only are some scientists rejecting the notion that restoration efforts do not improve macroinvertebrate biodiversity, some are even taking a step further, suggesting that not only is channel reconfiguration ineffective, it is actively harmful to the stream inhabitants that it is aiming to sustain (Tullos et al., 2009).

For this study, pre-restoration benthic macroinvertebrate data was collected by a previous Warren Wilson College student in the fall of 2018 with the use of Hester-Dendy multiplate samplers (Maxfield, 2019). The samplers, which provided information about specific invertebrate groups and their relative abundances, were compared to post-restoration macroinvertebrate data in hopes to assess whether or not stream restoration efforts indeed had positive effects on the benthic macroinvertebrate community. This research is meant to be a continuation of a long-term research project on the WWC restored streams and serves as a first look at the aftereffects of restoration.

Aquatic macroinvertebrates provide vital ecosystem services within streams by circulating allochthonous organic matter, regulating in-stream vegetation, and being vital food

sources for fish and other vertebrates (Spänhoff & Arle, 2007). Aquatic macroinvertebrates are typically viewed as ideal indicators for water quality and are particularly useful in determining success within stream mitigation projects (Jahnig et al., 2010, Li et al., 2018). Due to the fast flowing nature of waterways, short pulses of pollution can occasionally be missed via traditional water quality monitoring (Rubin et al., 2017). Because of this, macroinvertebrates often give a more nuanced insight into water quality and stream health than simple water chemistry analyses, making them a useful tool for water scientists and managers. In addition to this, utilizing benthic macroinvertebrates as indicator organisms for water quality can be advantageous because they are readily abundant, relatively easy to collect and identify, they are more sensitive to pollution than fish, and pollution tolerances are known for most taxa, which can give us a comprehensive picture of stream health (Barbour et al., 1999). Ephemeroptera, Plecoptera, and Trichoptera (EPTs) are orders of insects most notable for good water quality because they are relatively pollution intolerant compared to other macroinvertebrate groups (Righi-Cavallaro, 2010).

How drastically macroinvertebrate communities respond to restoration efforts is typically dependent on how intense restoration measures were (Spänhoff & Arle, 2007). The ability of species to recolonize the newly restored habitats are entirely dependent on the life histories of each individual species as well as their abundance in surrounding ecosystems. In other words, an increase in biodiversity can only be possible if there are reservoirs of novel species in surrounding habitats. For this reason, entire watersheds should be assessed during restoration initiatives to ensure the best chance at success for future projects (Spänhoff & Arle, 2007).

In order to have the best chance at success, project managers should take into account both the biotic and abiotic factors that affect stream invertebrates. One of the major factors in building a healthy aquatic invertebrate community is good stream substrate (Sheldon, 1968, Mazão & da Conceição, 2016).

A common practice for stream restoration is to add coarse gravel to the channel in order to improve in-stream habitat (Kristensen et al., 2011, Mueller et al., 2014). On Warren Wilson College's campus, contractors added various sizes of stone in the riffles, and where they could, excavated riffle material from the pre-restored channel in order to give the already existing benthic macroinvertebrate community an advantage for recolonizing. It should be noted however that this recycling of substrate did not occur in either of the streams monitored by the author.

In addition to substrate, vegetation within the stream is also important for the success of benthic macroinvertebrate communities. Aquatic plants, periphyton, and allochthonous material such as leaves and wood, are all very important for the survival of benthic invertebrates because they provide a good food source, better water quality, and important habitat (Burdett & Watts 2009). Specifically shredder insects which "shred" organic matter for food, are most targeted by restoration efforts as channel reconfiguration often results in a decrease in both in-stream and riparian vegetation (Louhi et al., 2011). In an experiment by Kaenel et al., the authors found when vegetation was removed from a stream, the number of invertebrates decreased by 65%. They also found it took 4-6 months for the plant matter within the stream to reestablish itself to pre-study conditions (1998). This research suggests that even after river restoration, a realistic amount of time should be expected before the plant and invertebrate communities are intact, and broader conclusions about the effects of river restoration on benthic invertebrates can be made.

It may take 4-6 months for primary production to be reinstated after restoration but this certainly isn't true for all stream autotrophs. More research as of late has been focused on the relationships between macroinvertebrates and aquatic bryophytes, or mosses, which many species are thought to be greatly dependent on. Aquatic bryophytes can be incredibly slow-growing and their recolonization abilities are poorly understood. Following reconstruction, moss abundance greatly decreases as

a result of heavy machinery use during channel reconfiguration (Louhi et al., 2011). It is possible that in restoration studies with low success, growth of invertebrate diversity may be limited by slow bryophytic reemergence not restoration failures (Louhi et al., 2011).

On Warren Wilson campus, eight streams were restored as a result of stream mitigation banking. The streams were excavated, remeandered to what they may have historically looked like, and substrate and plants were added. For this thesis, benthic invertebrate communities will be examined after stream restoration at four sites in two streams on Warren Wilson College campus by use of both qualitative and quantitative methods. The goal for this study is to compare pre-restoration populations to populations found a year after restoration in order to assess changes in water quality as a result of mitigation efforts.

## Methods

### *Study Site*

This study took place on two restored streams at Warren Wilson College. Warren Wilson College is located in Buncombe County of Western North Carolina, USA and sits within the Swannanoa valley of the Blue Ridge mountain range. Two streams, Farm Core (5D) and White Barn (5B) were examined. These streams are shown below in Figures 2, 3, and 4. For each stream, sampling was done in both the upstream and downstream sections. GPS coordinates for all site locations are displayed below in Table 1.

	Location of Upstream Site	Location of Downstream Site
Farm Core	-82°26'20.61", 35°36'38.47"	-82°26'27.71", 35°36'29.9"
White Barn	-82°27'9.37", 35°37'17.84"	-82°27'7.24", 35°36'51.66"

Table 1. Coordinates for upstream and downstream sites at Farm Core (5D) and White Barn (5B) streams.



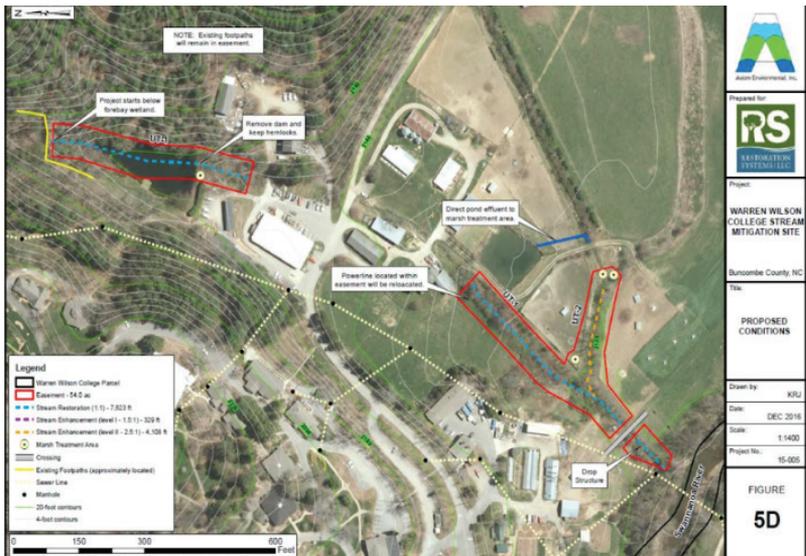


Figure 4. Map of Farm Core stream (5D) and the proposed plans for restoration at Warren Wilson College in Buncombe County, NC. Axiom Environmental, 2018.

The streams being restored are very small (1st or 2nd order) and are tributaries to the Swannanoa River. Both streams in this study have been unchanneled as a result of the stream restoration project. At White Barn, the stream was entirely rerouted and a new channel was excavated. Substrate was added to the new channel to increase habitat heterogeneity and induce colonization while outside of the channel a large riparian buffer was created to enhance overall ecosystem health (Figure 3). The Farm Core stream was excavated, then had riffle material, such as rocks and boulders, added. Many trees and a powerline were removed and a large riparian buffer was also created (Figure 4).

### Sampling Methods

Sampling took place in September 2020, approximately one year after restoration and two years after pre-restoration data was collected, to analyze the effects of stream restoration (Maxfield 2019). Kick net sampling, visual sampling, leaf pack sampling, and artificial substrate samplers were all used in order

to capture representatives from all different habitat types. Multiple sampling methods were used in order to make conclusions on both qualitative and quantitative aspects of restoration. All sampling techniques were done according to the North Carolina's Standard Operating Procedures for the Collection and Analysis of Benthic Macroinvertebrates (NC Department of Environmental Quality, 2016) in the upstream and downstream of each of the restored sections.

### *Qualitative Sampling*

For qualitative sampling, kick net, visual, and leaf pack sampling were used in compliance with Rapid Bioassessment Protocols to assess all different habitat types (Barbour et al., 1999). For kick net sampling, a standard D-frame dip net with standard mesh size of 500  $\mu\text{m}$  screen was used. Five minutes of kick sampling took place in each section of a stream. Kick sampling consists of "kicking" or disrupting substrate so organisms become unattached and drift into the D-frame dip net. Kick sampling took place over five minutes in each site in an effort for increased standardization. Visual sampling took place for ten minutes at each site, where rocks, leaves, and other substrate were visually inspected within the stream for macroinvertebrates. Due to the small size of these streams and the relative absence of decaying leaf matter, leaf pack samples consisted of just three handfuls of leaves from different sources within the stretch. By utilizing all three different techniques, we can gain the most comprehensive measure of biodiversity in each site by allowing us to exploit all of the many different habitats that can exist within a single stretch of stream.

### *Quantitative Sampling*

For quantitative sampling, Hester-Dendy samplers, a type of multi-plate artificial substrate sampler, were used. Ten Hester-Dendy multiplate samplers (Hester & Dendy, 1962) were used in each section of each stream sampled. Samplers were placed approximately five meters apart from each other but in some sections their placement was limited to areas where stream

depth was sufficient and access to samplers could be made. Each sampler was fixed to the shore with heavy duty fishing line and left out in the stream for three weeks before being removed and sorted on site. Samplers were retrieved in October of 2020.

Despite their extensive use in this project, many aquatic ecologists argue against the use of Hester-Dendy samplers as a mode of biomonitoring because samples are typically not fully representative of macroinvertebrate communities as certain taxa prefer habitat types that are not artificial substrate samplers, and as a result Hester-Dendy samplers often misrepresent relative abundances in streams (Barbour et al., 1999). One study however, found that Hester-Dendy samplers actually yielded higher species richness of Ephemeroptera, Plecoptera, and Trichoptera, the three orders most often used for indicating water quality (including in this paper) than kick sampling (Letovsky et al., 2019). This, in conjunction with their statistical abilities, make Hester-Dendy samplers a preferred method for analyzing EPT abundances in BACI experiments such as this one.

### *Preservation and Identification*

All specimens were collected in the field and placed into appropriately labeled jars. Macroinvertebrate samples from each Hester-Dendy replicate were put into their respective jars while macroinvertebrates from kicknet, visual, and leaf pack sampling were collected into a single jar for each of the four sites. Specimens were preserved in 70% ethanol until identification. They were then brought back to the lab where they were examined using a dissecting microscope and identified to family using *An Introduction to the Aquatic Insects of North America* by Merritt & Cummins (2008).

### *Data Analysis*

Qualitative data from kick net, leaf pack, and visual sampling were assessed using the Hilsenhoff Family Biotic Index (HFBI) in order to analyze water quality in each of the four sites (Hilsenhoff, 1987). Data from the three different sampling measures were assessed for taxon richness, diversity,

and dominance. Diversity was calculated using the Shannon Diversity Index and dominance was calculated from Simpson's D (Spellerberg & Fedor, 2003). Quantitative data from Hester-Dendy multiplate samplers was analyzed using statistical comparison. A two-way ANOVA was used to measure differences in EPT (Orders Ephemeroptera, Plecoptera, and Trichoptera) abundances between restoration as well as for the differences between upstream and downstream sections. The quantitative data obtained from post-restoration was compared to pre-restoration data in order to evaluate how the benthic macroinvertebrate communities in each site have changed since restoration was enacted.

## **Results**

### *Qualitative*

Qualitative data was obtained from each of the four sites post-restoration. Alpha diversity measures were calculated to obtain data regarding taxon richness, dominance, and diversity for each of the four sites. The results from each of these calculations are displayed in Figure 5 on the next page.

Alpha diversity metrics found that the downstream section of Farm Core had the lowest diversity, taxon richness, and highest dominance index of all four sites. Trends between upstream and downstream sections do appear to exist in each stream. The upstream sections of both streams were remarkably similar to one another with near identical metrics for diversity, richness, and dominance. Significance was not calculated for alpha diversity metrics due to a lapse in judgment by the author and further time constraints.

Benthic macroinvertebrate communities from before restoration were not qualitatively studied in addition to being identified to the higher functional taxonomic group of order. This discrepancy means there are not adequate accounts of prior biodiversity in the restored streams, thereby reducing our ability to compare alpha diversity with respect to restoration. Alpha diversity metrics from post-restoration instead serve to describe

the present state of these two streams. Future researchers studying the impacts of restoration should consider identifying sampling methods that provide both qualitative and quantitative data so comparisons of biodiversity can be done.

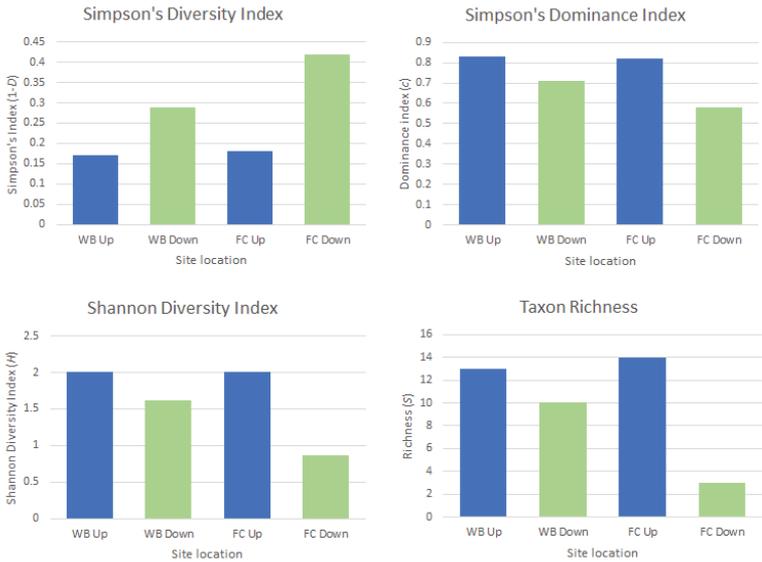


Figure 5. A) Simpson's Diversity Index ( $1-D$ ) for each of the four sites ( $wbu = 0.1714$ ,  $wbd = 0.2895$ ,  $fcu = 0.1799$ ,  $fcd = 0.4183$ ). B) Simpson's Dominance Index ( $c$ ) for each of the four sites ( $wbu = 0.8286$ ,  $wbd = 0.7105$ ,  $fcu = 0.8201$ ,  $fcd = 0.5817$ ). C) Shannon Diversity Index ( $H$ ) for each of the four sites ( $wbu = 2.011$ ,  $wbd = 1.616$ ,  $fcu = 2.012$ ,  $fcd = 0.8676$ ). D) Taxon richness for each of the four sites. Organisms were identified to the lowest practical taxon. For most organisms this was to family with the exception of snails and oligochaetes. Taxon richness is simply the number of taxa present in each of the sites ( $wbu = 13$ ,  $wbd = 10$ ,  $fcu = 14$ ,  $fcd = 3$ ). (fc = farm core, wb = white barn, u = upstream, d = downstream).

In addition to alpha diversity, qualitative data from the Rapid Bioassessment Protocols were assessed by use of the Hilsenhoff Family Biotic Index (HFBI) in an attempt to

determine water quality for each of the four sites (Hilsenhoff, 1987). The HFBI works by first recording all the families present in a given site and the number of individuals representing each family. Each family is assigned a tolerance value indicating how pollutant tolerant or intolerant they are. A water quality index score is given on the basis of how tolerant the organisms present are and the respective abundance of each. Scores range from 0-10, with 0 representing the best water quality and 10 representing the worst. The formula to calculate the water quality index score is given by the equation:

$$\text{FBI} = \frac{\sum(x*t)}{n},$$

where FBI = family biotic index, x = number of organisms in a given family, t = tolerance value of a given family, and n = total number of organisms in the sample. The water quality scores can then be paired with a table in order to interpret the results.

<b>Family Biotic Index</b>	<b>Water Quality</b>	<b>Degree of Organic Pollution</b>
0.00-3.75	Excellent	Organic pollution unlikely
3.76-4.25	Very good	Possible slight organic pollution
4.26-5.00	Good	Some organic pollution probable
5.01-5.75	Fair	Fairly substantial pollution likely
5.76-6.50	Fairly poor	Substantial pollution likely
6.51-7.25	Poor	Very substantial pollution likely
7.26-10.00	Very poor	Severe organic pollution likely

Table 2. Interpretation of water quality from FBI scores generated by using the Hilsenhoff Family Biotic Index (HFBI) (Hilsenhoff, 1987).

## White Barn

Results from the HFBI found that the White Barn stream was considerably healthy after restoration. The upstream site possessed a water quality score of 3.9 denoting “very good” water quality with unlikely pollution present. The downstream site had only marginally worse water quality with a water quality score of 4.6 denoting “good” water quality with possible but improbable pollution present. The families present and their relative abundances are outlined in Tables 3 and 4 below.

Family	#	Tolerance value	Product
Simuliidae	2	6	12
Heptageniidae	7	3	21
Baetidae	1	5	5
Leuctridae	2	0	0
Hydropsychidae	13	4	52
Glossosomatidae	1	1	1
Elmidae	1	4	4
Aeshnidae	2	3	6
Tabanidae	1	5	5
Tetrastemmatidae	1	8	8
Psephenidae	3	4	12
Stratiomyidae	1	7	7
Leptoceridae	15	4	60
Total	50	Sum	193
$FBI = \Sigma(x*t)/(n)$	3.86	“Very good”	

Table 3. The macroinvertebrate community composition for the upstream site of White Barn stream. The biotic index score was calculated from the equation  $FBI = \Sigma(x*t)/(n)$  where FBI = family biotic index, x = number of organisms in each family, t = tolerance value, and n = total number of organisms in the sample. The score for the upstream site is 3.86 indicating “very good” water quality with a low likelihood of pollution present.

Family	#	Tolerance value	Product
Sialidae	1	4	4
Baetidae	9	5	45
Heptageniidae	6	3	18
Siphonuridae	1	4	4
Hydropsychidae	50	4	200
Philopotamidae	5	3	15
Chironomidae	11	6	66
Simuliidae	14	6	84
Culicidae	1	8	8
Physidae	2	8	16
Total	100	Sum	460
FBI = $\Sigma(x*t)/(n)$	4.60	“Good”	

Table 4. The macroinvertebrate community composition for the downstream site of White Barn stream. The biotic index score was calculated from the equation  $FBI = \Sigma(x*t)/(n)$  where FBI = family biotic index, x = number of organisms in each family, t = tolerance value, and n = total number of organisms in the sample. The score for the upstream site is 4.60, indicating “good” water quality with possible but improbable pollution present.

### *Farm Core*

Macroinvertebrates in the downstream section of Farm Core consisted of only three taxa - chironomid larvae<sup>1</sup>, blackfly larvae, and oligochaete worms. For Farm Core’s upstream site, the water quality was also “good” with a score of 4.5 while its downstream site ended up being denoted as “poor” with a whopping score of 7. This is unsurprising though, given just how murky and polluted the downstream site looks in this photo I took. At this site the majority of the invertebrates downstream

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1. It is important to note that none of the chironomids present in any of the samples belonged to red-blooded species whose dominance is indicative of very poor water quality.

were aquatic worms or midge larvae, so coming to this conclusion was not a shock to me.

<b>Family</b>	<b>#</b>	<b>Tolerance value</b>	<b>Product</b>
Aeshnidae	14	3	42
Baetidae	1	5	5
Chironomidae	1	6	6
Dixidae	3	1	3
Elmidae	4	4	16
Gomphidae	2	3	6
Heptageniidae	2	3	6
Hydropsychidae	15	4	60
Leptoceridae	2	4	8
Leuctridae	2	0	0
Odontoceridae	2	0	0
Right-handed snail	24	7	168
Simuliidae	1	6	6
Tabanidae	1	5	5
Total	74	Sum	331
FBI = $\Sigma(x*t)/(n)$	4.47	“Good”	

Table 5. The macroinvertebrate community composition for the upstream site of Farm Core stream. The biotic index score was calculated from the equation  $FBI = \Sigma(x*t)/(n)$  where FBI = family biotic index, x = number of organisms in each family, t = tolerance value, and n = total number of organisms in the sample. The score for the upstream site is 4.47 indicating “good” water quality with possible but improbable pollution present.

Family	#	Tolerance value	Product
Chironomidae	8	6	48
Oligochaeta	9	8	72
Simuliidae	1	6	6
Total	18	Sum	126
FBI = $\Sigma(x*t)/(n)$	7.00	Poor	

Table 6. The macroinvertebrate community composition for the downstream site of Farm Core stream. The biotic index score was calculated from the equation  $FBI = \Sigma(x*t)/(n)$  where FBI = family biotic index, x = number of organisms in each family, t = tolerance value, and n = total number of organisms in the sample. The score for the upstream site is 7.00 indicating “poor” water quality with a presence of pollution likely.

### *Quantitative*

Quantitative data for three orders Ephemeroptera, Plecoptera, and Trichoptera, was analyzed via R Studio by use of a two-way ANOVA. The two-way ANOVA tested three things, it compared EPT abundance between sites, EPT abundance before and after restoration, as well as the interaction between site location and time of sampling. The P-value used to determine significance was 0.05. The source code for both ANOVAs are located in the appendix of this publication.

In addition to the two-way ANOVA, taxon richness for the samplers was also examined in order to compare community compositions with respect to restoration. Because Hester-Dendy samplers are skewed towards certain groups of organisms, the results from taxon richness for quantitative data should not be interpreted literally as any actual measure of biodiversity or abundance. It serves to instead show gross differences in community structures with respect to both time and site location. By examining the number of taxonomic groups present, it was found in both streams that there were fewer taxa present in the

downstream sites compared to the upstream sites both before and after restoration, though significance is not known.

Data for each of the sites outlining what orders were present in each replicate sampler and their total abundances can be found in Tables 8, 9, 11, and 12.

### *White Barn*

EPT abundance decreased greatly in the downstream site as a result of mitigation, though this difference is not statistically significant, likely as a result of a small sample size. EPT abundance was statistically the same in up- and downstream sites following restoration with a t-test returning a P-value of 0.99.

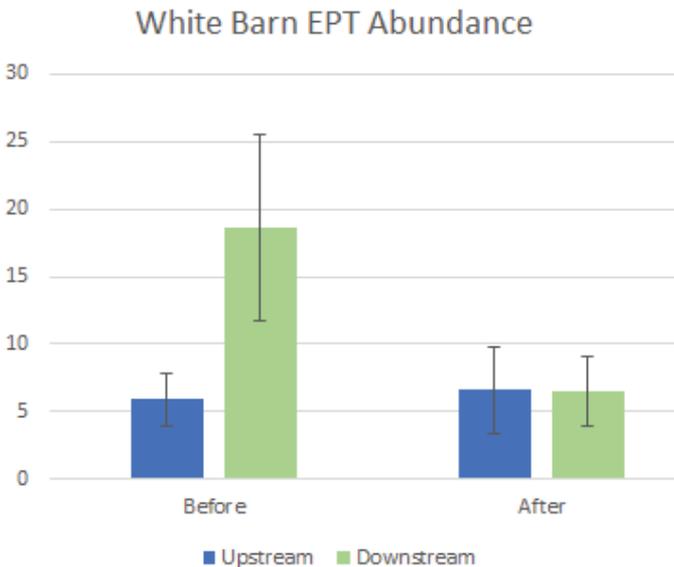


Figure 6. White Barn EPT abundance before and after restoration for both up- and downstream sites. Error bars denote the standard error for each of the sites.

The two-way ANOVA found no significant difference in EPT abundances with respect to site ( $0.09 > 0.05$ ) or time of sampling ( $0.24 > 0.05$ ). The interaction effect characterized by “time:site” was also found to be insignificant ( $0.10 > 0.05$ ) (Table 7).

White Barn	P-value	Significant?
Time	0.2427	No
Site	0.0875	No
Time:Site	0.1010	No

Table 7. Significance table showing results from the two-way ANOVA for White Barn stream. The two-way ANOVA (1) analyzed the difference in EPT abundance before and after restoration, (2) analyzed the difference in EPT abundances between sites, and (3) analyzed the interaction effect between site location and time of sampling (before or after restoration). Significance was determined if the P-value was less than 0.05.

Taxon richness was slightly lower in the downstream site both before and after restoration in the White Barn stream (2018 7>6, 2020 8>6). Taxon richness did not change greatly in either of the sites from before to after restoration (upstream 7 to 8, downstream 6 to 6). Before restoration, the downstream section of White Barn was dominated by EPTs, with fly larvae, aquatic worms, and dragonflies making up the other present taxa. After restoration, the downstream site had these same six taxa with EPTs being the dominant orders. This implies that community composition did not change after restoration with respect to Hester-Dendy multiplate samplers.

Sampler ID	Plecoptera	Ephemeroptera	Trichoptera	EPT Total
KWU1	9	0	1	10
KWU2	2	0	0	2
KWU3	0	0	0	0
KWU4	9	10	5	24
KWU5	2	1	0	3
KWU6	4	1	0	5
KWU7	0	0	2	2
KWU8	N/A	N/A	N/A	N/A
KWU9	N/A	N/A	N/A	N/A
KWU10	N/A	N/A	N/A	N/A
Total	26	12	8	46
Average	3.71429	1.71429	1.14286	6.57143

Sampler ID	Diptera	Haplotaixida	Megaloptera	Annelida	Anisoptera
KWU1	2	0	0	1	0
KWU2	0	0	0	0	0
KWU3	0	1	0	0	0
KWU4	0	0	0	0	0
KWU5	6	2	0	0	1
KWU6	1	0	0	0	0
KWU7	1	1	1	0	0
KWU8	N/A	N/A	N/A	N/A	N/A
KWU9	N/A	N/A	N/A	N/A	N/A
KWU10	N/A	N/A	N/A	N/A	N/A
Total	10	4	1	1	1
Average	1.42857	0.57143	0.14286	0.14286	0.14286

Table 8. Macroinvertebrate orders and their abundances collected via Hester-Dendy multiplate samplers in the upstream section of White Barn.

Sampler ID	Plecoptera	Ephemeroptera	Trichoptera	
KWD1	4	0	11	
KWD2	0	1	0	
KWD3	0	0	0	
KWD4	0	11	0	
KWD5	0	10	0	
KWD6	0	1	1	
KWD7	N/A	N/A	N/A	
KWD8	N/A	N/A	N/A	
KWD9	N/A	N/A	N/A	
KWD10	N/A	N/A	N/A	
Total	4	23	12	
Average	0.666666667	3.833333333	2	
Sampler ID	EPT Total	Diptera	Haplotaxida	Zygotera
KWD1	15	3	1	0
KWD2	1	12	2	0
KWD3	0	1	0	0
KWD4	11	11	9	0
KWD5	10	7	0	2
KWD6	2	3	0	1
KWD7	N/A	N/A	N/A	N/A
KWD8	N/A	N/A	N/A	N/A
KWD9	N/A	N/A	N/A	N/A
KWD10	N/A	N/A	N/A	N/A
Total	39	37	12	3
Average	6.5	6.166666667	2	0.5

Table 9. Macroinvertebrate orders and their abundances collected via Hester-Dendy multiplate samplers in the downstream section of White Barn.

## Farm Core

No EPTs were found in the downstream section of Farm Core after restoration. This is not a significant difference from before, however, as there was only a single EPT (Order: Trichoptera) found downstream of Farm Core prior to restoration resulting in an average abundance of 0.125 EPTs per sample (Figure 7). EPT abundance was statistically very different in up- and downstream sites following restoration with a t-test returning a P-value of 0.0002.

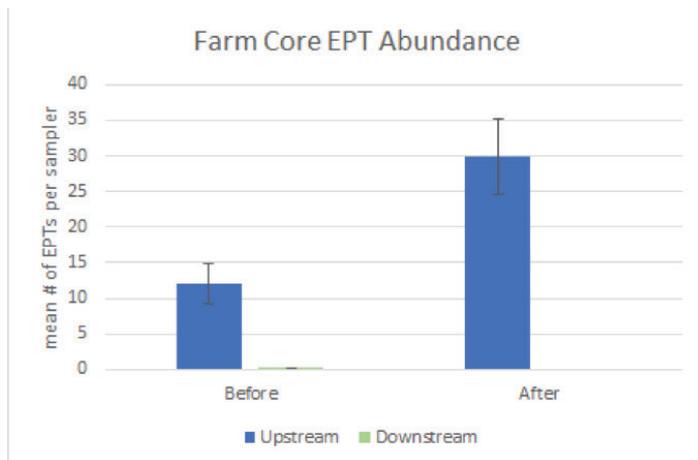


Figure 7. Farm Core EPT abundance before and after restoration for both up- and downstream sites. Error bars denote the standard error for each of the sites.

The two-way ANOVA found significant differences between EPT abundances with respect to site ( $9.19 \times 10^{-7} < 0.05$ ) and time of sampling ( $0.004 < 0.05$ ). The interaction effect characterized by “time:site” was also significant ( $0.01 < 0.05$ ) (Table 10). The three P-values are likely heavily skewed due to the considerable increase in EPTs upstream before and after restoration. EPT abundances doubled in the two years following pre-restoration sampling with an average of 12 EPTs per sampler in 2018 to an average of 30 EPTs per sampler in 2020. Because upstream sites should be unaffected by restoration, this increase is not important to the study and is likely an effect of climatic differences between years.

Farm Core	P-value	Significant?
Time	0.00376	Yes
Site	$9.19 \times 10^{-7}$	Yes
Time:Site	0.01103	Yes

Table 10. Significance table showing results from the two-way ANOVA for Farm Core stream. The two-way ANOVA (1) analyzed the difference in EPT abundance before and after restoration, (2) analyzed the difference in EPT abundance between sites, and (3) analyzed the interaction effect between site location and time of sampling (before or after restoration). Significance was determined if the P-value was less than 0.05.

Taxon richness was slightly lower in the downstream site both before and after restoration in the Farm Core stream (2018 7>6, 2020 8>4). Taxon richness increased after restoration by one taxa group in the upstream site and decreased by two taxa groups in the downstream site (upstream 7 to 8, downstream 6 to 4). Before restoration, the downstream section of Farm Core was dominated by snails and dipterans EPTs, with beetles, dragonflies, and a single caddisfly making up the other present taxa. Based on the taxa present, the downstream section of Farm Core was likely moderately polluted prior to restoration. After restoration, the downstream site had four taxa present: left-handed snails, dipteran larvae, tubifex worms, and amphipods, all of which are pollutant tolerant groups characteristic of degraded streams. After restoration, pollutant tolerant organisms were more favored and the macroinvertebrate community composition changed negatively with respect to Hester-Dendy multiplate samplers.

Sampler ID	Plecoptera	Ephemeroptera	Trichoptera	EPT Total
KFU1	8	0	22	30
KFU2	N/A	N/A	N/A	N/A
KFU3	8	1	19	28
KFU4	12	4	11	27
KFU5	12	0	12	24
KFU6	23	4	35	62
KFU7	12	8	5	25
KFU8	7	2	22	31
KFU9	0	1	0	1
KFU10	20	3	17	40
Total	102	23	143	268
Average	11.3333	2.5556	15.8889	29.7778

Sampler ID	Gastropoda	Diptera	Coleoptera	Haplotaxida	Megaloptera
KFU1	0	6	0	0	0
KFU2	N/A	N/A	N/A	N/A	N/A
KFU3	3	4	0	0	0
KFU4	1	7	1	1	1
KFU5	2	2	0	0	1
KFU6	0	10	0	0	0
KFU7	2	4	1	0	0
KFU8	0	7	0	0	0
KFU9	0	1	0	0	0
KFU10	0	2	2	0	0
Total	8	43	4	1	2
Average	0.8889	4.7778	0.4444	0.1111	0.2222

Table 11. Macroinvertebrate orders and their abundances collected via Hester-Dendy multiplate samplers in the upstream section of Farm Core.

Sampler ID	Gastropoda	Diptera	Haplotaxida	Amphipoda
KFD1	3	12	0	0
KFD2	1	5	0	1
KFD3	2	24	2	0
KFD4	0	16	0	1
KFD5	0	10	0	0
KFD6	N/A	N/A	N/A	N/A
KFD7	N/A	N/A	N/A	N/A
KFD8	N/A	N/A	N/A	N/A
KFD9	0	26	0	0
KFD10	1	4	0	2
Total	7	97	2	4
Average	1	13.85714286	0.285714286	0.571428571

Table 12. Macroinvertebrate orders and their abundances collected via Hester-Dendy multiplate samplers in the downstream section of Farm Core.

## Discussion

After restoration, there was no increase in EPTs downstream in either of the studied streams (Figures 6 and 7). There are several possible explanations for why EPT abundance and taxa richness are not increasing even after successful restoration of habitat heterogeneity. Some of these include limitations due to slow-growing bryophyte communities, external climatic effects, limitations in dispersal abilities amongst species, and previous historical disturbances (Louhi et al., 2011). It is also incredibly possible that just simply not enough time has passed since restoration was enacted.

There is an idea among stream restoration efforts that sometimes it “has to get worse before it gets better.” Szymańska et al. echoed this in their study when they examined one species

of Ephemeroptera for the purpose of determining success in stream restoration projects. They found that immediately following reconstruction, local mayfly populations plummeted, but as time went on, the species was able to adapt and colonize sections within the stream they weren't present in prior (2020). Morphological restoration often requires heavy equipment like tractors and backhoes in order to re-meander streams and restore habitat heterogeneity. The process of channel reconstruction is very unnatural as stream disturbances go, and is often more stressful than the initial channelization or habitat degradation it aims to resolve. As a result, invertebrate abundance and biodiversity are typically expected to plummet initially after restoration (Szymańska et al., 2020). Still, the hope is that by excavating and rerouting streams to their more natural state, over time they will become healthier and more productive than before restoration.

One of the major factors affecting recovery times in restored streams is the varying recolonization abilities for each macroinvertebrate species. There are many avenues for recolonization to occur but species reintroduction is largely dependent on refuge populations in healthy unrestored streams. This requires organisms to migrate actively or passively from either up- or downstream of the restored channel. Novel species can also colonize the newly restored stream via aerial dispersion as well as passive transport by wind, water, or animal vector (Spänhoff & Arle, 2007).

Immigration of novel species is not only limited to the dispersal capabilities of the species in question but also by the amount of habitat available in the stream as well as competition from already established populations (Spänhoff & Arle, 2007). As a result, a shift in community structure should be expected in the years following restoration as disturbance-adapted species typically arrive first and dominate before the community stabilizes, resulting in a more heterogeneous community composition (Spänhoff & Arle, 2007). This typically manifests as a shift in dominance from one functional feeding group to another. For example, Albertson et al. found that in one restored

stretch of river, the dominance drastically shifted from filter-feeding caddisflies to highly-sensitive grazing mayflies (2011).

Refuge populations near restored streams are vital for macroinvertebrate recolonization. Restoration at Warren Wilson College is occurring on a relatively large scale, which is sensible because of the importance of considering entire watersheds rather than single stretches of degraded stream, but could hinder a timely recolonization, as many of the macroinvertebrate reservoirs near campus will be disturbed as a result of the mitigation. Assuming there are healthy reservoirs of organisms near the streams on campus, benthic macroinvertebrate communities still typically undergo a shift in community structure in the years following restoration as disturbance-adapted species typically arrive first and dominate before the communities stabilize, resulting in a more heterogeneous community composition (Spänhoff & Arle, 2007).

Another explanation for delayed improvements could be a result of slow vegetation growth. This research was performed only one year after restoration, meaning only one growing season was able to take place. There is the possibility that despite improved habitat heterogeneity, streams could simply not have enough plant life in or around the stream necessary to support these invertebrates. A lack of vegetation is certainly possible in both restored streams as all the surrounding trees and shrubs were cleared in order to maneuver heavy equipment for channel restoration. This surely resulted in a decrease in allochthonous material which many “shredder” insects which as their name implies, shred organic matter for food, require to survive.

A delay in results could simply be an issue of timing and not a restorative failure, but the possibility that pollution sources outside of the restoration project are contributing to the decline in EPT abundance in restored streams, should not be ignored. Poor water quality can easily limit the success of these ecosystems and outweigh any effects from restored heterogeneity. In other words, restored habitat heterogeneity may be achieved but as long as water chemistry is suboptimal, habitat heterogeneity

doesn't have the opportunity to work (Palmer et al., 2010). This very well could be happening to the restored streams on campus, especially Farm Core, which flows through the college's farm, autoshop, recycling and composting facility, and horse paddock. Each of these establishments are strong contenders for nutrient, sediment, and inorganic pollution. Pollution occurring from any one of these sources could be sufficient enough to explain the absence of EPTs downstream of Farm Core. For streams with multiple stressors at work, restoration efforts must go beyond morphological and structural changes (Palmer et al., 2010).

Any of the reasons mentioned earlier could be limiting EPT success in the restored streams, but there is of course the possibility that recovering habitat heterogeneity simply isn't beneficial. In a study by Lepori et al., it was found that habitat heterogeneity was indeed higher in restored sites compared to unrestored, channelized stretches, which makes sense as this is the primary goal of most river restoration projects targeting channelized waterways (2005). Despite habitat heterogeneity being significantly higher in these restored sites, fish and invertebrate diversity was no greater than the reference sites being used as controls (Lepori et al., 2005).

Another study, Louhi et al., echoed this and theorized that habitat heterogeneity may not be playing as large of a role as previously thought (2011). The study suspected that northern European streams channelized for the transport of logs in the sixteenth century, resulted only in a partial decline of overall habitat heterogeneity. It is also theorized that in the 20-30 year period between the suspension of log driving and the first surveys, enough time passed for stream invertebrate populations to recover without anthropogenic assistance (Louhi et al., 2011). This suggests that in affected streams, a need for increased habitat heterogeneity is overrepresented and in fact it may be better to simply let "nature do the healing."

Results of restoration projects may not always fulfill the goals they set out to achieve, but this isn't to say positive outcomes don't exist. For example Jähnig et al. found that despite a lack of response from benthic macroinvertebrate communities,

there was a strong improvement for both riparian beetles and vegetation after morphological restoration (2009). This suggests that an increase in benthic macroinvertebrate diversity should not be the only measure of success in restored streams and more attention should be given in the future to additional in-stream taxa as well as riparian species (Louhi et al., 2011).

One problem with many of the studies done on restored streams is that success for restoration efforts aren't always agreed on, and the majority of projects lack realistic goals for the actions that are taking place (Rubin et al., 2017). Both scientists and managers studying the efficacy of stream restoration should be sure to maintain realistic goals throughout the years following stream restoration (Spänhoff & Arle, 2007). Due to the complexities amongst each species and their varying recolonization abilities, an increase in biodiversity is first, never guaranteed, and second, should only be expected after several years, assuming all conditions necessary for success are met. Spänhoff & Arle conclude that mitigation projects can only serve as a "template for enhancement of macroinvertebrate diversity, but the dynamic nature and the individuality of the streams will [ultimately] determine the result" (2007).

For increased success, several authors made suggestions for future restoration efforts. Palmer et al. suggested gentler restoration attempts instead of whole channel reconstruction. More moderate efforts include improving storm-water treatment systems and establishing robust riparian buffers (2010). These solutions may bring about more success and as a result would likely be more cost effective in the long-term. Louhi et al. urged for the use of a "double-control" in restoration projects, meaning that two control sites would be used to compare communities in restored streams, one site exemplifying target water quality and community compositions and another that is degraded similarly to the restored channel pre-mitigation (2011). By using a double-control, the impacts of restoration can be addressed with much more confidence.

If Warren Wilson College students participate in more

stream restoration projects in the future, they should be sure to consider gentler restoration attempts and a more rigorous study design consisting of a double-control. Warren Wilson College students continuing research on the White Barn and Farm Core streams could also learn from some previous studies. For example, in the study by Louhi et al., macroinvertebrate composition and salmonid abundance was examined both three years before and three years after restoration via a BACI experimental design (2011). To make this project more comprehensive, data from previous years should be investigated. Warren Wilson classrooms have a long history of experiential learning in the two restored streams and future research should synthesize any available datasets or past collections.

Future studies should also be sure to include climate data as a part of their research. Climatic variability is continuing to increase as a result of climate change and flooding events are expected to become even more commonplace. As this shift takes place, research on the effects of restoration on macroinvertebrate communities will become increasingly more important but additionally, even more muddled as another confounding factor is added to an already poorly understood system (Louhi et al., 2011).

## **Conclusion**

The importance of long-term monitoring for the White Barn and Farm Core streams cannot be overstated. Downstream sections in both of these streams did not show an increase in EPT abundances, which could be occurring for any of the reasons previously discussed. In order to determine if morphological restoration has had any effect on macroinvertebrate communities, surveys should be conducted at least every fall for the next 10 years. Only with patience will we understand the full consequences of restoration efforts on Warren Wilson's streams.



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## Appendix

### R Source Code

```
# two-way ANOVA for Farm Core stream
farm<-aov(ept ~ time + site + time:site)
> summary(farm)
      Df Sum Sq Mean Sq F value Pr(>F)
time    1   892    892  9.931 0.00376 **
site    1  3453   3453 38.455 9.19e-07 ***
time:site 1   662    662  7.375 0.01103 *
Residuals 29  2604    90
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

# two-way ANOVA for White Barn stream
> White_Barn_ANOVA<-aov(wept ~ wtime + wsite +
wtime:wsite)
> summary(White_Barn_ANOVA)
      Df Sum Sq Mean Sq F value Pr(>F)
wtime    1  138.6  138.63  1.434 0.2427
wsite    1  306.7  306.67  3.173 0.0875 .
wtime:wsite 1  281.1  281.12  2.909 0.1010
Residuals 24 2319.4  96.64
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

**"America Loves Me?"**

**by Katherine Wilson**



# **No Trucks Moved, By Nobody: The Minneapolis Teamsters Strike and Union Socialism**

## **Abstract**

In the summer of 1934, during the Great Depression, a small but scrappy local branch of the Teamsters Union used Trotskyist tactics to battle police in the streets of Minneapolis and win concessions from their employers. Despite a lack of support from both the Teamsters bureaucracy and other communist agitators, the leaders of Local 574 mobilized a large swath of Minneapolis' working class for their cause. Seeking increased wages and union recognition, the Teamsters drew from the Trotskyist roots of their leaders in developing their strategy. They found success through the idea of the transitional program in combination with some very creative tactics, including teenage motorcycle couriers and spying secretaries. This research explores the role of Trotskyism in the American context of union socialism and seeks to explain Local 574's success. Furthermore, this research situates the strike within a broader view of labor history by examining the national mood leading up to the strike, the resulting interactions with police and employers during the strike, and the far-reaching consequences on both state and federal legislation.

## **Bridget Palmer**



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## Introduction

The summer of 2020 began with death. After George Floyd died at the hands of the Minneapolis Police Department, the response was near instantaneous. Protests and demonstrations began in Minneapolis but spread across the nation, eventually even the world. Minneapolis is a city with a strong history of radicalism and militant action, but when did that begin? How did a city in the upper Midwest come to be a hub for leftists? A Teamsters strike during the Great Depression is one place to look. The streets of Minneapolis would have looked eerily similar in 1934. Enormous brawls between strikers and the police broke out on multiple occasions, injuring dozens of people and killing a handful. The National Guard mobilized and patrolled the streets to enforce a city-wide curfew. Why was this strike so consequential? Because it had experienced leaders, utilized creative tactics, established a large network of supports, and developed systems of support outside of both the state and the Teamsters bureaucracy.

The climate of labor relations in Minnesota in the early 1930s was not favorable to labor organizers. Minneapolis was the distribution hub of the upper Midwest, with large industries like coal or agriculture employing thousands of drivers each. In Minneapolis, the Citizens Alliance had a strong membership and maintained the city's open shop status. The Citizens Alliance, a group of local business owners supported by many in the local government, effectively functioned as the inverse of a union— it represented employers and their interests against those of their employees. They enjoyed the support of the Minneapolis Police Department, whom they often called upon to interfere in labor disputes. They employed a variety of tactics to maintain control in Minneapolis, including keeping files on organizers, cooperating with the FBI, and using spies to discover unionization attempts in their infancy.<sup>1</sup> Until 1933 or so, Minneapolis' open shop

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1. Donna T. Haverty-Stacke, *Trotskyists on Trial: Free Speech and Political Persecution since the Age of FDR*, (New York: NYU Press, 2016), 32.

status<sup>2</sup> seriously inhibited the recruitment of potential union members across the city. The passage of the National Industrial Recovery Act (NIRA) in 1933, however, ushered in a wave of support for unions. Title I of NIRA authorized the President to establish industrial regulations which would aid economic recovery, as well as protecting the collective bargaining rights of unions.<sup>3</sup> Membership increased for many national unions including the Teamsters. The renewed pro-union sentiment combined with the disheartening conditions in Minneapolis pushed the city and its workers towards their limits. The battle to transform Minneapolis would be fought uphill, every victory hard-won.

### **The Teamsters**

The term “teamster” originally referred to men who drove teams of animals for deliveries but expanded to include truck drivers in the early twentieth century. The current International Brotherhood of Teamsters (IBT) was formed in 1903 after a merger of the Team Drivers International Union and the Teamsters National Union. The first president of the IBT was Cornelius Shea who served from 1903 to 1907. He was replaced in August 1907 by Daniel J. Tobin, an Irish immigrant then living in Boston. Tobin would serve as the president until 1952.

Under Tobin’s leadership, the IBT developed its reputation as a conservative union, one which is generally averse to striking and more willing to cooperate or negotiate with employers. Teamsters strikes were uncommon when compared to other unions, in large part because a two-thirds vote was required to approve any strike action, and because the president could deny benefits to the strikers if he thought they had acted too quickly. Between the internal bureaucracy and domination of the Citizens

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2. “Open shop” refers to a workplace in which a union represents all employees but does not require potential employees to join or financially support the union as a condition of employment.

3. NIRA was a very controversial act. As the regulations increased, support from business owners decreased. The Supreme Court declared Title I unconstitutional in 1935. It is generally considered to be a policy failure.

Alliance, Minneapolis hardly seemed ready for a major strike.

Teamsters Local 574 was small in 1933, less than 200 members representing only a sliver of the companies operating in Minneapolis. At the time, the union was led by Carl Skoglund and Ray Dunne. Both men were Trotskyists and members of the Communist League of America (later renamed the Socialist Workers Party), the American branch of Leon Trotsky's International Left Opposition. Skoglund had immigrated to the United States two decades earlier after being expelled from Sweden for organizing a soldier's mutiny.<sup>4</sup> Dunne was the child of immigrants and got his start in agriculture, but bounced from job to job for most of his early life. He was introduced to the labor movement as a teenager by a branch of the Industrial Workers of the World (IWW) in North Dakota.<sup>5</sup> Dunne was one of the most visible communists operating in Minnesota at the time. Skoglund and Dunne were considered outsiders within the Teamsters due to their radical beliefs—Tobin was quite clear that he would not welcome communists into the Teamsters' ranks. He created much distance between "rank-and-file" Teamsters and radical organizers like Skoglund and Dunne.<sup>6</sup> Skoglund and Dunne had both been founding members of the Communist Party in America but were expelled in the 1920s because of their support for Leon Trotsky over Joseph Stalin. They were outsiders both in the American communist movement and in the IBT, which would later cause them to forge unique alliances. Despite the odds being stacked against them from the beginning, they saw an opportunity to radically change the lives of their fellow workers.

### **Rising Tension**

The first real victory of Local 574 occurred in the winter of 1933-34. Leading members of the union—Carl Skoglund, Ray Dunne, and the newly arrived Farrell Dobbs—began organizing drivers at a coal yard in the city. Dunne was working in a coal

4. Bryan D. Palmer, "Red Teamsters." *Jacobin*, Oct. 14, 2014.

5. Lila Johnson Goff, "Oral History Interview with Vincent Raymond Dunne," 27 Apr. 1969, Minnesota Historical Society.

6. Palmer, "Red Teamsters."

yard at the time and felt like that had a serious opportunity to increase wages, though it took two years to actually initiate a strike.<sup>7</sup> Their other goals were union recognition and the right to organize “inside” workers. Skoglund was also working in coal and drumming up support for a union. In autumn 1933, Skoglund’s employers warned him that he was risking his job by agitating fellow drivers. This warning backfired- Skoglund doubled down on his commitment to unionizing the coal yard and began planning a strike in conjunction with the Dunne brothers.<sup>8</sup> They orchestrated the strike outside of both the IBT’s internal bureaucracy and the mediation procedures established by the National Industrial Recovery Act. A warm snap had depressed the coal industry that winter but a sudden cold front in early February, 1934 gave them the leverage they needed.<sup>9</sup> The strikers locked up half of the trucks in their coal yards and used the other half to patrol Minneapolis, targeting scab drivers. They seized coal from the scab drivers and delivered it to working class neighborhoods at no cost to the residents. Within hours, 65 of the 67 coal yards in Minneapolis shut down. The same strategy was used again for the next two days. Jeopardizing the heating supply during a bitterly cold week predictably caused significant opposition from the city and the Citizens Alliance. They attempted to find scab drivers to deliver coal, but Skoglund and Dunne had beat them to the unemployed. The Teamsters had ensured that unemployed drivers in the city would support the strike rather than scab for the coal companies.<sup>10</sup> Since they could not hire scab drivers, the coal owners partially capitulated to the strikers’ demands for wage increases and union recognition in only two and a half days. Coal drivers would receive a small pay raise and recognition of the union. This small strike was hard won and ultimately successful beyond its goal. The victory legitimized Local 574 in the eyes of many drivers across the city, increasing

7. Johnson, “Interview with Dunne.”

8. Bryan D. Palmer, *Revolutionary Teamsters: The Minneapolis Truckers Strike of 1934*, (Leiden: Brill, 2013), 50.

9. Haverty-Stacke, *Trotskyists on Trial*, 33.

10. Johnson, “Interview with Dunne.”

membership sharply. However, local coal companies still kept wages relatively low and withheld the union's right to exclusive collective bargaining.<sup>11</sup>

Buoyed by their victory in the coal yards and with few other options left to unionize inside workers, Local 574 began preparing for a general driver's strike. Members rented out a large hall that could be used as a hub- a combination headquarters, infirmary, and kitchen. They also created a Women's Auxiliary to run the headquarters, composed of the wives, sisters, mothers, and daughters of the Teamsters. The next step was reaching out to farmer's organizations in the surrounding area to get their support for a potential strike. Without Teamsters, farmers would have fewer ways to transport or sell their products, so reaching an understanding between the two parties would be crucial in keeping Minneapolis fed. Farmers would be allowed to deliver directly to grocers and supply the strikers with food as well. One of the most important farmers' organizations was the Hennepin County branch of the National Farm Bureau, which provided meat, produce, and milk to the strike commissary.<sup>12</sup> The Teamsters also made contact with organizations representing the unemployed, to deter scabbing once the strike began. Many of the unemployed joined the picket lines in support and discouraged scabbing within their ranks.<sup>13</sup>

## Strike

Local 574 issued their demands on April 30, 1934. They were few and straightforward: official recognition of the union, a wage increase to an average of \$27.50 per week, overtime pay, shorter working hours, and right to represent "inside workers," those who work in distribution centers but do not drive. The last demand marked a very important break from the IBT's official party line of craft unionism (organization of "skilled" workers only); they would instead advocate for militant

11. Palmer, "Red Teamsters."

12. "3 Farm Organizations Now In Agreement With 574," *The Organizer*, July 18, 1934.

13. "Unemployed Support Strike," *The Organizer*, July 18, 1934.

industrial unionism which included workers of all skill levels. By taking a stance of industrial unionism, they were acting against not just the bosses, but the IBT bureaucracy as well. Trucking companies resisted immediately, less than a dozen at first but quickly growing to 150 companies throughout the city. The union overwhelmingly voted to strike in response. The strike began on May 16, 1934. They then established a Strike Committee of 100 men representing most of the distribution companies in Minneapolis which coordinated all major actions, handled the day-to-day business of striking, organized relief to strikers' families, and ran the strike's newspaper, *The Organizer*.

Most commercial transportation in Minneapolis was shut down in days, with the exception of certain farmers who managed their own deliveries. They had made a deal with the Teamsters to allow delivery directly to grocers, rather than to the market district as was standard. Situated close to the Mississippi River and major roadways, the market district was the heart of commerce in Minneapolis. Strikers and their allies ran picket lines, demonstrations, and speeches outside of the strike headquarters and in the market district. Just three days later, the first incident of police violence occurred. Strikers attempted to prevent scabs from unloading a truck in the market district, but instead were beaten by the Minneapolis Police and a number of hired private guards. The injured strikers were carried back to 574's headquarters, closely followed by the police. The police were refused entry and beaten on the sidewalk. Two of them were left unconscious on the street.<sup>14</sup>

In response, the Minneapolis police deputized a few hundred members of the Citizens Alliance. The following Monday, the police and Citizens Alliance attempted to open the market district for deliveries. Hundreds of strikers and members of the Women's Auxiliary arrived at the scene to prevent the delivery, armed with clubs. Police prepared to shoot. But before they could, a truck full of strikers drove into their midst, ensuring 14. Unfortunately Local 574 had not yet started publishing their strike bulletin when this incident occurred. As a result, firsthand, detailed accounts are very difficult to come by.

that they could not shoot strikers without also shooting each other. The next day, May 22, the strikers drove the police out of the market district and away from their headquarters. A riot ensued, which resulted in the death of two deputies and the injury of over 20 police and strikers.

Shortly thereafter, the Strike Committee approached Chief of Police Mike Johannes to negotiate a truce. They were aided by the Building Trades Council, the Central Labor Council, and the Teamsters Joint Council. The truce they signed promised an end to picketing for 24 hours, so long as the police and Citizens Alliance did not attempt transportation of goods. However, Johannes declared that the police would resume transportation when the truce expired, so Local 574 declared that they would resume picketing. The truce was to be very temporary. The city government expected more violence and appealed to Governor Olson for help. Olson mobilized the 34th Infantry Division of the National Guard, though he did not go so far as to deploy them. Olson was a member of the Minnesota Farmer-Labor Party<sup>15</sup> so he hesitated to risk alienating his labor supporters. On May 25 the strikers and employers agreed to a contract which would reinstate the fired union members, officially recognize the union, establish seniority, include “inside” workers in the union, and create a no-discrimination clause in their contracts. The union members approved it by a high margin. The situation in Minneapolis calmed down until July. It was at this point that the employers went back on their agreement to include “inside” workers in the union recognition. The Strike Committee remobilized and resumed picketing on July 17. This time, strikers were ordered by their leadership to be unarmed. The police, however, began carrying riot guns which used buckshot instead of regular bullets. Governor Olson once again mobilized but did not deploy the

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15. The Minnesota Farmer-Labor party was a left-wing political party which operated between 1918 and 1944. It was related to the Progressive and Populist movements and dominated Minnesota politics during the Great Depression. In 1944 it was merged with the smaller Minnesota Democratic Party to create the new Minnesota Democratic-Farmer-Labor Party which still operates today as the state’s affiliate to the national Democratic Party.

National Guard.

Friday, July 20, was by far the most violent day of the strike. The Minneapolis Police Department announced that it would transport a scab truck to make a delivery and shoot to kill any strikers who attempted to interfere. Word circulated amongst the strikers who then rushed to the scene. Police escorted two scab trucks to the Slocum Bergren Company on Third Street North to unload merchandise, then escorted the trucks away. As the patrol of strikers arrived in their truck to prevent delivery, a third scab truck also turned onto Third Street, escorted by twelve police cars. The strikers blocked the third truck, intending to prevent any further delivery of goods, but over 100 police officers fired on them. They shot at the strikers' truck with shotguns, then turned to fire into the crowd on the surrounding streets. The workers attempted to move their injured comrades out of the line of fire to safety, but the police sprayed them with buckshot indiscriminately. By the time the shooting had ended, 67 people were injured and two lay dying.<sup>16</sup>

Henry Ness and John Belor died of their injuries shortly after the shooting. Ness was well known within the labor scene of Minneapolis after 16 years of service in various unions, several of those years with Teamsters Local 574. Other strikers donated blood and provided emotional support as doctors worked to remove the 38 slugs in Ness' chest and back. His last words were "Tell those boys not to fail me now!"<sup>17</sup> Because of his popularity with fellow workers in Minneapolis, Ness became a martyr for the cause. That Monday's edition of *The Organizer* declared him "the first martyr of [Local] 574," proving that leadership believed more workers would die before the fight was won. His death galvanized the strike. On July 24, 40,000 people attended his funeral and 100,000 lined the streets of Minneapolis in solidarity.<sup>18</sup> Local 574 erected a temporary monument on the street corner where Ness

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16. "The Testament of Henry Ness," *The Organizer*, July 23, 1934. The details in this section are all drawn from this account.

17. "Testament of Henry Ness."

18. "40,000 Attend Ness Funeral," *The Organizer*, July 25, 1934.

was shot to commemorate his sacrifice.<sup>19</sup>

After the shooting, labor organizers in Minneapolis began referring to Chief of Police Michael Johannes as “Bloody Mike.” He would only serve two years in the role before retiring in 1935. Many members of the public called for his impeachment, along with Mayor A. G. Bainbridge. A public commission ordered by Governor Olson later determined that the police had shot to kill despite their safety never being endangered. No weapons were found in the possession of strikers at the scene, nor did they attack the police.

On July 26, Olson again mobilized the National Guard and declared martial law. The National Guard began to issue permits to truck drivers allowing them to make deliveries, as well as enforcing a curfew and patrolling the city. On August 1, the National Guard raided then seized the strike headquarters, arrested the leadership of Local 574, and detained the leaders in a stockade at the St. Paul fairgrounds. They were released the next day thanks to the lobbying of other strikers and their supporters. The National Guard returned the headquarters to Local 574 and performed a raid on the Citizens Alliance office, though no arrests or seizures were made there. This raid was more to create an appearance of equal treatment than anything else. In the wake of the raids, employers rejected a proposed contract written by federal mediator Father Francis J. Haas.<sup>20</sup>

By mid-August, the National Guard had issued permits to thousands of drivers. The strike continued anyway. On August 21, the Citizens Alliance accepted a new proposal written by Father Haas which would accept most of the union’s demands. Local 574 also accepted the conditions and the contract was ratified. The final contract ended the strike immediately, guaranteed the reinstatement of all strikers on seniority without discrimination, established a preferential list of strikers to be rehired before companies could make new hires, ensured a clause of nondiscrimination for the union, set a date and procedure for

19. John Belor never achieved the same martyr status as Henry Ness. His funeral was a smaller affair but still drew thousands of attendees.

20. “Bosses Turn Down Haas Proposal,” *The Organizer*, July 27, 1934.

a union election, and raised the minimum hourly wage of drivers to 50¢ (40¢ for inside workers and helpers).<sup>21</sup> The Teamsters had won.

### **Strategies and Ideology**

Local 574 developed a few new tactics during the strike which would be utilized by other unions later on. The first was the “flying picket,” a driver who patrolled the city looking for scab drivers. It also allowed them to keep an eye on the police. 574 practically had a fleet of flying pickets spread across Minneapolis. More crucially, though, the strikers cultivated a strong relationship with the unemployed and organizations for the unemployed. It is important here to remember the wider national context for the strike- the United States was deep in the throes of the Great Depression, and the national unemployment rate was at nearly 25% going into 1934. Finding scab drivers would normally be very easy under those conditions. But because the Teamsters had the foresight to foster relationships with the unemployed, hiring scab drivers became more difficult. The initial lack of widespread scabbing gave the Teamsters a serious advantage in negotiating.

Having a hub for strike organizing proved crucial as well. Because they had fostered a relationship with farmers and created a Women’s Auxiliary, they were able to run a functioning cafeteria to feed the strikers and their families. The “hospital wing” of the headquarters was staffed by the Women’s Auxiliary in conjunction with sympathetic doctors and nurses who volunteered their free time.<sup>22</sup> Treating injured strikers from the relative safety and privacy of their headquarters prevented them from being turned away or arrested at the city hospitals. They also developed relationships with secretaries at the various trucking companies who would then report back to the Strike Committee about the bosses’ plans.<sup>23</sup> Fascinatingly, they hired a gaggle of teenagers on motorcycles to relay messages and reports to strikers across the

21. “The Settlement Terms,” *The Organizer*, August 22, 1934.

22. Palmer, “Red Teamsters.”

23. Palmer, “Red Teamsters.”

city.<sup>24</sup>

Unlike most Teamsters, Local 574 was composed of communists, Trotskyists in particular. 574's leaders during the strike- Carl Skoglund, Farrell Dobbs, and the Dunne brothers (Ray, Miles, and Grant)- were all known and celebrated within the Trotskyist movement, especially in Minneapolis.<sup>25</sup> Trotsky himself had once called Ray Dunne the most effective labor leader in the United States.<sup>26</sup> Their political beliefs are incredibly important to understanding the course of the strike and its fallout. Trotskyists believe in the theory of permanent revolution rather than two-stage revolution, meaning that the revolutionary class must pursue its own goals without forming alliances with opposing classes as was dictated by Vladimir Lenin and Joseph Stalin. Had they been followers of Lenin or Stalin, the theory of two-stage revolution would dictate that they ally with the bourgeoisie to achieve a fully industrialized society then break that alliance to pursue a communist revolution for the working class. However, their belief in permanent revolution discouraged the leaders of Local 574 from allying with the broader IBT, who in their minds represented capitalist bureaucracy and the petite bourgeoisie. They believed that mass mobilization of the working class towards democracy would create social revolution, so they formed relationships with farmers and the unemployed to engender class solidarity. Trotskyists believed in proletarian internationalism rather than the "socialism in one country" theory of Stalin, and advocated for a transitional program between capitalism and socialism, one which would meet the needs of the working class while striving towards actual

24. Palmer, "Red Teamsters."

25. The younger Dunne brothers, Miles and Grant, are not as well remembered as Ray. However, they were also considered leaders in the Minneapolis labor movement and were heavily involved with the 1934 strikes. Miles was a charming public speaker, while Grant was known for his quiet toughness. For more information about the Dunne brothers, see Bryan D. Palmer, *Revolutionary Teamsters*, 46.

26. Anja Witek, "Dunne, Vincent Raymond (1889–1970)," Minnesota Historical Society.

workers' control of the state. The methods they employed while striking, first in February then again in the summer, were akin to a transitional program. They created a large network of support which would meet the strikers' material needs for food and medical care as they fought to gain real power in Minneapolis.

Their method of striking exemplified Trotskyist thought put into practice. This is why the strike was so effective and so threatening. They weren't looking to create alliances outside of the working class and directly questioned the validity of the Teamsters' national leadership. They refused to accept the authority of the Communist Party or the Communist International that had expelled and betrayed them.

Despite their victory, Local 574 was expelled by the IBT in March of 1935 by Tobin and replaced by a new chapter with new leadership, Local 500. Because the Teamsters were (and still are) a mostly conservative union, their actions were seen as deeply out of line. Six months later, the IBT passed a resolution which explicitly prohibited communists from union membership. After serious pressure from other Teamsters, Tobin brokered a deal to merge Locals 500 and 574 into the new Local 544. The members of Local 544, under the leadership of Skoglund, Dobbs, and Dunne, assisted in organizing efforts across the Twin Cities in a variety of other industries. They remained under socialist control<sup>27</sup> until 1941.

### **Subsequent Repression**

Broader criminal syndicalism laws had arisen during World War I to quell anti-war sentiment, but they also targeted radical labor unions and parties throughout the Great Depression and World War II. "Criminal syndicalism" was defined vaguely to mean advocating for criminal behavior (sabotage, assault, terrorism) to achieve political or social goals. Loose definitions allowed police, prosecutors, and judges to apply the laws as they saw fit. Minnesota specifically allows state courts and the

27. It was not uncommon during this time for American radicals to use socialist and communist interchangeably. Ray Dunne, for example, described himself as a socialist, a communist, and a Trotskyist.

governor to interfere in the actions of labor unions when acts of criminal syndicalism are allegedly being carried out.<sup>28</sup> In response to this strike and others, both the state and federal governments began drafting new legislation which targeted the Teamsters, alongside other militant labor unions.

The Alien Registration Act, more commonly known as the Smith Act, criminalized advocacy for the overthrow of the United States government, either by force or by violence, and required all non-citizen adult residents to register their status with the federal government. It was enacted in June 1940. The act was used primarily to target “extremists,” who ranged from socialists and anarchists to fascists. The first serious trial resulting from the Smith Act came after a raid of the Socialist Workers Party (SWP) offices in Minneapolis and St. Paul on June 27, 1941. The FBI seized some boxes of papers, two red flags, and a photograph of Leon Trotsky.<sup>29</sup>

The SWP had splintered from the Communist Party of the United States of America (CPUSA) as part of the larger schism between followers of Leon Trotsky and followers of Joseph Stalin. Its membership saw it as a vanguard party with the goal of creating working class unity.<sup>30</sup> They controlled Local 544 of the Teamsters union, which angered Tobin. Tobin first sought to break the Local from the inside. He befriended a splinter group within the union called the “Committee of 100” which opposed the Trotskyist leadership.<sup>31</sup> When that proved ineffective, he turned to the state government of Minnesota and to the Federal Bureau of Investigation for support.<sup>32</sup> The resulting legal troubles weakened the union’s ability to defend itself. In 1941 he removed from power the remaining Trotskyists leading Local 544 by leveraging the power of the Minnesota

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28. Mn. Code Ann. § 186-6 (1917).

29. Witek, “Dunne, Vincent Raymond,” Minnesota Historical Society.

30. Haverty-Stacke, *Trotskyists on Trial*, 32.

31. Barry Eidlin, “‘Upon this (Foundering) Rock’: Minneapolis Teamsters and the Transformation of US Business Unionism, 1934-1941,” *Labor History* 50, no. 3 (2009): 256.

32. Eidlin, “‘Upon this Foundering Rock’” 257.

Labor Review Board. When it appeared that the Congress of Industrial Organizations (CIO) would incorporate the former leadership, Tobin used his government contacts to orchestrate a raid on Local 544's headquarters and ensure federal sedition charges under the Smith Act. Twenty-nine party members and Teamsters union members were indicted a month later by a federal grand jury. Those arrested included Carl Skogland, Ray Dunne, and Farrell Dobbs. The trial began in late October. Five of the 29 defendants were acquitted due to lack of evidence, one committed suicide, and 18 were found guilty of violating the Smith Act. They received sentences between 12 and 16 months.<sup>33</sup> Skoglund was placed under deportation orders until his death in 1960, though the actual deportation was never carried out. The arrests and convictions broke socialist control of Local 544 and seriously weakened the Trotskyist presence in Minneapolis. It also demonstrated the enormous divides between local and national union organizers, craft unionism and industrial unionism, and the various sects of communism all vying for power and influence.

### **Conclusion**

The Teamsters strike was a much needed breath of fresh air for the labor movement. After years crippled by the Great Depression, it was a restoration of the militant union activity seen before the stock market crash. Despite the police violence, state repression, and factional politics, the Teamsters triumphed so soundly that Minneapolis became a haven for organized labor instead of scabs. A small, scrappy group of Trotskyists took on a seemingly impossible challenge and won because they utilized creative tactics and experienced leadership. They refused to compromise their political stances even when ostracized by other leftists, recognizing that they could achieve their goals through militant class solidarity instead of leftist unity. They proved that a movement doesn't need the support of the rich or the powerful, just the support of the people it's fighting for. A sentiment

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33. Eidlin, "Upon this Foundering Rock," 257.

expressed in the inaugural run of *The Organizer* will sound familiar to those who followed the events of the summer: “We help our own.”<sup>34</sup> The struggle hasn’t changed, only evolved.



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34. Ladies Auxiliary Give Benefit Dance,” *The Organizer*, June 25, 1934.

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