Perpetua: The UAH Journal of Undergraduate Research

Volume 2 | Issue 2 Article 8

5-1-2018

Perpetua, Volume 2, Issue 2, Spring 2018

Follow this and additional works at: https://louis.uah.edu/perpetua

Recommended Citation
(2018) "Perpetua, Volume 2, Issue 2, Spring 2018," *Perpetua: The UAH Journal of Undergraduate Research*: Vol. 2: Iss. 2, Article 8.
Available at: https://louis.uah.edu/perpetua/vol2/iss2/8

This Full Issue is brought to you for free and open access by LOUIS. It has been accepted for inclusion in Perpetua: The UAH Journal of Undergraduate Research by an authorized editor of LOUIS.

Perpetua

THE UAH JOURNAL OF UNDERGRADUATE RESEARCH

VOLUME 2 | ISSUE 2 | SPRING 2018



THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

PERPETUA

Perpetua

UAH Journal of Undergraduate Research

Volume 2, Issue 2



STAFF PAGE

Editor in Chief: Emily Hartsell

Assistant Editors in Chief: James Shelton

Review Board Coordinators:

Augustus Wintzell

Ali Sultan

Manohar Devarasetty

Peer Review Staff:

Patrick Taylor

Ben Tran

Production Editor:

James Shelton

Production Staff:

Maxwell Fox

Alex Matlock

Marketing Intern:

Amber Brasher

Finance Editor:

Andrea Charnock

Finance Staff:

Calvin J. Mahlik

Web Editor:

Danielle Bryant

Web Design Staff:

Nehal Patel

Faculty Advisors:

Dr. Gordon MacGregor (Biological Sciences)

David Cook (Student Research Programs & Honors Program)

Dr. Yu Lei (Chemical Engineering)

LETTER FROM THE EDITOR

Dear Reader,

I am proud to introduce the third issue of *Perpetua*. Although we are a very young publication, we have grown to serve as a cornerstone of the undergraduate research community at UAH. We owe a great deal of thanks to our advisors as well as the various graduate students, faculty, administrators, and alumni who have been instrumental in our growth and success as a publication.

Our primary mission is to create a publication platform for UAH undergraduates and in that we have been successful. We also serve to support the reputation of UAH as a premiere research university offering research opportunities in all disciplines. As you browse the table of contents, you will see that this diversity of opportunity is reflected in the articles published in this issue.

Perpetua as an organization has grown and evolved since our previous issue was published. Our ever-growing staff is stronger and more diverse than ever before and we have made some notable accomplishments in recent months. This spring we welcomed our first intern as part of a program that will continue for years to come. We established a review board which has paved the way for unprecedented cooperation between faculty and undergraduate researchers. We built and fostered relationships with other organizations at UAH and in the greater Huntsville community. Most recently, we sponsored a research panel at Health Careers Day which served to promote undergraduate research at UAH to high school students. We hope to continue serving our UAH community in these roles and more in coming years.

I hope that you find something of interest to you within our pages and that you will be inspired to make your own contribution to research at UAH.

Sincerely,



Emily Hartsell
Editor-in-chief
Perpetua

SPECIAL THANKS

Perpetua is a cooperative effort and publication would be impossible without the support of various individuals and organizations across campus and throughout the greater Huntsville community. We offer special thanks to all who have contributed their time, expertise, financial support, and hard work to *Perpetua.* A few of our biggest contributors are recognized below.

We thank the Student Government Association for providing sufficient funding to print and distribute physical copies of this issue. We would also like to thank Dr. William Wilkerson and the Honors College for their commitment to providing financial support to *Perpetua*.

Next, we would like to extend our thanks to the faculty advisors who have provided invaluable insight and guidance to our editorial staff. We thank Dr. Gordon MacGregor of the Biological Sciences Department for his assistance in evaluating submissions and improving our peer review and revision processes. We thank Dr. Alanna Frost of the English Department for helping *Perpetua* establish our first review board.

Finally, we thank every graduate student, alumnus, and professor who served as a reviewer for one of the manuscripts featured in this issue. Without such individuals volunteering their time and expertise *Perpetua* would not be able to provide our services to the UAH community.

Table of Contents

Title	Author	Department(s)	Page
North Alabama Ecological Forecasting: Spatial Modeling of the Fragmentation of Local Species Habitat from Increasing Urbanization in North Alabama	Helen Baldwin, Emily Kinkle, and Nicholas McVey	Department of Atmospheric Science	1
Crafting British Superiority: A Study of Eighteenth and Nineteenth Century Cookbooks	Meg Bojarski	Department of History	9
An Investigation of Copper Catalysts for Propylene Epoxidation	Hayden Fowler	Department of Chemical and Materials Engineering	14
Measuring the Effects of the Alexander Technique on Posture and Tension in Student Violinists and Violists	Rebekah Frederick	Department of Mechanical and Aerospace Engineering Department of Kinesiology	21
Gentrification and Police Brutality	LaDeana Phillips	Department of Political Science	32
Economic Indices: An Analysis of the Space Industry	Emily Sexton	Department of Economics	37
Observations on the Reproductive Biology of the Darter Fish *Etheostoma kennicotti* in Response to Gill Parasite Infections	Zeina Sleiman and Corinne Peacher	Department of Biological Sciences	48

North Alabama Ecological Forecasting: Spatial Modeling of the Fragmentation of Local Species Habitat from Increasing Urbanization in North Alabama

Helen Baldwin, Emily Kinkle, and Nicholas McVey
Department of Atmospheric Science

Abstract **–** Alabama is one of the most biodiverse states in the United States, including the greatest diversity of aquatic species. As urbanization continues to increase in Alabama, this biodiversity is at risk. NASA DEVELOP partnered with the Land Trust of North Alabama to identify sensitive habitats that are at risk from urbanization within Madison and Limestone counties. The Land Trust of North Alabama works to preserve land, primarily in Madison and Limestone counties, and encourages stewardship through environmental education. The team conducted a supervised classification of land class type, utilizing data from Landsat 5 Thematic Mapper (TM), Landsat 8 Operational Land Imager (OLI), and Shuttle Radar Topography Mission Version 4 (SRTM) to identify land cover changes and areas most vulnerable to future urbanization. By incorporating land classification analysis and additional parameters indicative of urbanization, the team produced an urbanization prediction tool and a landscape fragmentation map. The urban prediction tool identified land highly suitable for development and found that 25% of highly suitable land will be urbanized by 2045 using the measured 0.87% growth rate. Ecological impact was established using observation data for species of interest to the project partners. These tools will enable the Land Trust to target high risk areas of land for preservation.

I. Introduction

With just over 3,600 square kilometers of biodiverse land, Madison and Limestone counties in northern Alabama (**Figure 1**) have undergone significant development in recent years and urbanization is expected to continue to increase (U.S. Census Bureau, 2012). In order to provide for the growing population, land is often converted for agricultural and residential use (Bostick, 2017). More large-scale agricultural fields lead to increased runoff pollution, which negatively impacts native species' habitats (Ongley, 1996). In addition to agricultural development, urban growth is also a concern for local species' habitats due to fragmentation and subsequent competition and reduced carrying capacity. From 1980 to 2010 the Madison County population increased by over 137,000 people and the city of Huntsville, located in Madison, is one of America's fastest growing cities. Limestone County grew by over 36,000 people from 1980 to 2010 (U.S. Census Bureau, 2012). The Land Trust of North Alabama is specifically concerned that rapid growth and development in Madison and Limestone counties will negatively impact the natural landscapes of the region, and more importantly, the habitats of threatened and endangered species. This boom in urbanization highlights the need to expand conservation efforts. Without sufficient conservation efforts, many species in the area could be at risk of habitat loss, including 30 endangered and threatened species (U.S. Fish & Wildlife Service, n.d.).

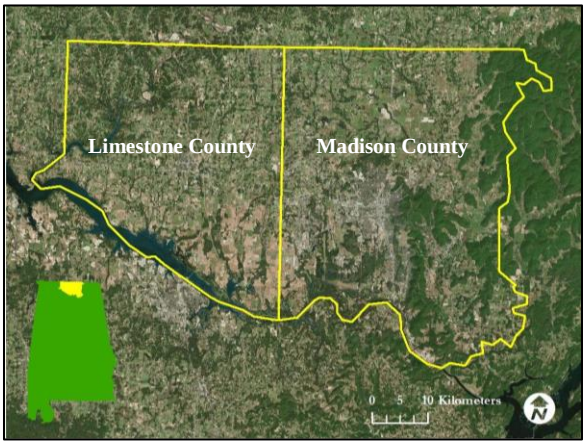


Figure 1: *Madison and Limestone counties in northern Alabama*

The Land Trust works with local government officials to acquire land for conservation and to educate the public, including private landowners, about the natural habitats and ecosystems that are present in the local area (Land Trust, 2017). There are some restrictions at the federal level that encourage conservation, such as building restrictions in flood plains mandated by the Federal Emergency Management Agency. However, the Land Trust works to preserve land that is not protected at the federal level and thus would otherwise be available for

development. Currently, the Land Trust primarily obtains land in Madison County. Due to increasing populations and urbanization, they seek to preserve land in Limestone County as well. The Land Trust's decision-making heavily relies on field studies and outsourced or volunteered research. To assist the Land Trust with decision-making regarding conservation, urbanization patterns from 1986 to 2017 were analyzed. Then, Fuzzy Logic in ArcMap 10.4.1 was used to create the Favorability for Development Map that forecasted urbanization to 2045. A Species Impact Tool was created to assist the Land Trust in effectively choosing land for conservation by assessing the potential impact on habitats from land change. Once the land is obtained, the Land Trust can allocate the necessary resources to preserve and protect areas of interest that are home to threatened or endangered species. Aside from informing acquisition of land, the Land Trust will be able to use the tools developed from this project to educate the public and land owners in the area about the potential impact of development on local species habitats and promote conservation efforts.

II. Data Acquisition

The team acquired Landsat 5 Thematic Mapper (TM) Top of Atmosphere Reflectance (TOA) orthorectified with Fmask and Landsat 8 Operational Land Imager (OLI) TOA Reflectance image collections through Google Earth Engine (GEE) with a code developed by the team. The code retrieved the least cloudy images that covered the study area for each year of the study period. Image pairs were mosaicked and clipped to the study area. Shuttle Radar Topography Mission (SRTM) v4 data were downloaded from cgair-csi.org to provide the topography of the region (Jarvis, Reuter, Nelson, Guevara 2008). Landsat 8 OLI and Landsat 5 TM both have 30 m resolution, with a repeat cycle of 16 days.

The Land Trust identified several species of particular interest due to their native status and rare nature, including the green salamander (*Aneides aeneus*) and Morefield's leather flower (*Clemamtis morefieldii*). The team also acquired data on the American black duck (*Anas rubipes*), the cave salamander (*Eurycea lucifuga*), and the northern slimy salamander (*Plethodon glutinosus*). Green salamander observations within the study area were acquired from Andrew Cantrell, a student researcher at Alabama Agricultural and Mechanical University (Cantrell, 2011), and Rebecca John from Auburn University (John, 2017). Data for American black duck observations were retrieved from the eBird website as a text file and converted to a comma-separated values (CSV) file for use in Esri ArcGIS. Cave salamander and northern slimy salamander data were acquired from Christine Easterwood at the U.S. Army Garrison, Redstone Arsenal, and Rebecca John at Auburn University (John, 2017). Morefield's leather flower data were acquired from Michael Barbour at the Alabama Natural Heritage Program, Auburn University (Alabama Natural Heritage Program, 2016).

Location data for colleges, fire stations, hospitals, and public schools were acquired from the Homeland Infrastructure Foundation-Level Data (HIFLD) Subcommittee open data webpage. HIFLD data incorporated locations of interest beyond the Madison and Limestone county borders, such as large cities just outside of the study area, to more accurately represent the distribution of infrastructure affecting potential urban growth. The two most recent 30-meter land cover layers available from the Multi-Resolution Land Characteristics Consortium (MRLC) website were acquired in order to determine the average urban growth rate for the study area.

III. Data Processing

The Landsat 8 and Landsat 5 imagery acquired by GEE had undergone a Top of Atmosphere (TOA) correction to convert the remotely sensed digital numbers to reflectance values. The SRTM data covering Limestone and Madison counties were acquired as two separate rasters and mosaicked in ArcMap 10.4. The Landsat series and SRTM rasters were clipped to the study area. An additional shapefile was created to encompass the study area and surrounding cities. HIFLD infrastructure data were clipped to the shapefile, and distance rasters for each dataset were made using the Euclidean Distance tool in ArcMap 10.4.1.

Maximum Likelihood Classification was conducted for the least cloudy Landsat imagery collected from 1984 to 2016. First, a total of seven land cover classes were distinguished, including forest, agriculture, barren, water and three levels of urbanization. 100 polygons were created for each class by using 2016 Worldview data as the guide to land cover type. Three band math ratios were tested using the Maximum Likelihood Classification: Normalized Difference Vegetation Index (NDVI), Normalized Difference Built Index (NDBI), and Enhanced Built-Up and Bareness Index (EBBI). When a visual comparison with the National Land Classification Database (NLCD) demonstrated that this approach

resulted in a large numbers of ponds where no ponds exist, the number of classes was reduced to three: Developed, Undeveloped, and Water. Gross inaccuracies remained, and the Maximum Likelihood Classification approach was discarded in favor of the NLCD. This may have been a result of focusing on using the least cloudy image from each year, rather than utilizing a seasonality approach and incorporating the least cloudy image from the same season. Within the scene for one year, the least cloudy images could be up to 6 weeks apart and the scenes varied from a collection month of January to November. Since forested areas may look bare in a winter scene and vegetated in a summer scene, these differences in collection time may have impacted the usability of the land classification.

To forecast urbanization, Fuzzy Logic Modeling was used in ArcMap 10.4. First, the Fuzzy Membership tool was used to assign Fuzzy Membership values to each of the datasets being used. The team determined that the most appropriate membership for distances to colleges, fire stations, public schools, and hospitals was a linear membership because people prefer to live near these types of infrastructure. An MSLarge membership was used for the reclassified NLCD, meaning that the input values with larger values have a higher membership which declines sharply after the mean. After assigning the Fuzzy Memberships, the data were clipped to the study area shapefile and all of the Fuzzy Memberships were input into the Fuzzy Overlay tool. The "AND" operator was used to create the final suitability layer based on a high fuzzy membership in all the component layers.

IV. Data Analysis

The average total change of developed land per year was calculated using the 2006 and 2011 NLCD. All pixels classified as developed (i.e. High, Medium, Low, and Open) were counted, the 2006 total was subtracted from the 2011 total, and then divided by the intervening years. This process generated an urban growth rate of 1% per year for northern Alabama, which can be useful for identifying overall growth, but will not identify any volatile years within the period that had higher or lower growth. This calculation was repeated with a Maximum Likelihood land classification for the Landsat 8 and Landsat 5 imagery for years 2006 through 2011 to provide higher temporal resolution data than the NLCD. However, the Maximum Likelihood land classification misidentified large areas when compared with the NLCD. In addition, the Maximum Likelihood land classification average urban growth rate was approximately 2%. The accuracy of the NLCD classification is 85% (Wickham et al., 2013) and incorporates a ground truth verification process. Due to the obvious errors of the Maximum Likelihood classification and the verified accuracy of the NLCD, further analysis used the temporally limited growth rate derived from the NLCD rather than the visual classification created.

Using the NLCD classification growth rate, development was projected through 2100. To understand the significance of this urban growth rate, the number of years it would take this 1% urban growth per year to develop all of the highly favorable lands was calculated. Highly favorable lands are open lands that have the lowest average distance from fire stations, colleges, hospitals, and public schools. Zoning codes were unavailable for the entire study area, and so were not included. The estimated growth was subtracted from the total area (km^2) of the highly favorable classification from the Favorability for Development Map. This process shows the estimated number of years it would take at 1% urban growth per year to develop all of the highly favorable lands.

After urban growth was projected, an impact analysis was conducted on local species habitats to assess where potential land development could impact local species. The point location observations of each species served as a basis for the species impact map. The impact of urbanization does not need to be directly on top of the existing species habitat to impact the species; therefore, a buffer was created around each point of the species data in efforts to better represent the impact of encroaching urbanization. Songbirds typically need a buffer of at least 45 to 100 meters, and sometimes can extend to 200 meters (Hannon, 2012). Mammals can require a buffer ranging from about 90 to 300 meters around their habitat (Bilecki, 2003). Fish and aquatic species need a relatively small 10 to 100 meter buffer (Jones, Helfman, Harper, Bolstad, 1999). Ultimately, a 250 meter buffer was selected to represent the maximum necessary buffer size for most species. After the buffers were created, each species' habitat was intersected with the data from the Favorability for Urban Development Map.

V. Analysis of Results

Areas within Madison and Limestone counties that are favorable for urban development were identified (**Figure 2**). Low favorable land was located along the county line and covered 35% (1,293 km^2) of the study area. Medium favorable land covered 28% (1,059,542 km^2) of the study area. High

favorable land accounted for approximately 1,057 km^2, or almost 20% of the total study area. The location of the low favorable land could be due to the geography of the region, as the Tennessee River flows along the southern edge of Limestone and Madison counties. Additionally, the region along the eastern Madison county line is more mountainous than the rest of the study area. These areas may be more difficult to access, and in the case of the areas along the Tennessee River, may face more restrictions in terms of building residential areas.

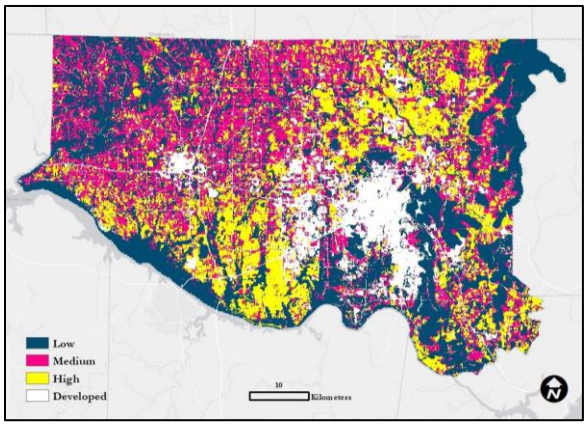


Figure 2: *The Favorability for Urban Development Map shows the probability that an area within Limestone and Madison counties will become urbanized.*

Based on the current urban growth rate in these counties, it is projected that by 2045 approximately 25% of all highly favorable land will be developed (**Figure 3**). The 25% increase in developed areas across north Alabama would result in 20% of the total land area in Madison and Limestone counties being considered developed land. Furthermore, if the approximately 1% growth rate remains constant into the future, all highly favorable lands are projected to be developed by the year 2100. As Limestone and Madison counties continue to grow, it is possible that the 1% growth rate will increase over time.

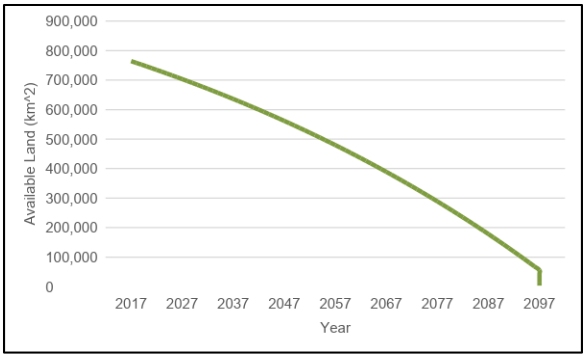


Figure 3: *Total projected amount of highly favorable land available (in square kilometers) in north Alabama from the 2017 through 2101*

The area of each species habitat is relatively small compared to the study area due to the limitations of the observation datasets utilized. The American black duck had the largest amount of habitat in areas highly favorable for future land development, and accounted for the highest overall threat with 2.7 km^2 of their habitat falling into a high or medium category of development (**Table 1**; **Figure 4**). With such a large amount of the American black duck habitat falling into high and medium levels of potential development, the species will likely be negatively impacted by future development.

The green salamander, cave salamander, and northern slimy salamander all had similar amounts of habitat that fell into each development favorability level. This is most likely due to their similar habitat requirements. The salamanders' habitats primarily fell into the low favorability classification, which means that the potential impact from future urban growth is minimal in the near future. This is likely due to their cave habitat lying in areas where development is likely not to occur. The Morefield's leather flower had the lowest amounts of area in any of the development favorability categories. The threat of impact on the American black duck habitat is the greatest of all species studied for this project with 0.19% of habitat at high suitability for development.

Species	Habitat in High (m^2)	Habitat in Medium (m^2)	Habitat in Low (m^2)	Total Habitat (m^2)
American Black Duck *Anas rubripes*	$1.7x10^6$ (0.19)	$1.0x10^6$ (0.11)	$6.0x10^6$ (0.69)	8.7×10^6
Green Salamander *Aneides geneus*	$6.2x10^4$ (0.01)	$3.0x10^5$ (0.04)	$7.4x10^6$ (0.95)	7.8×10^6
Morefield's Leather Flower *Clematis morefieldii*	$1.1x10^4$ (<0.01)	$4.9x10^4$ (0.03)	$1.7x10^6$ (0.97)	1.76×10^6
Northern Slimy Salamander *Plethodon alutinosus*	$6.2x10^4$ (0.01)	$3.0x10^5$ (0.04)	$7.4x10^6$ (0.95)	7.8×10^6
Cave Salamander *Eurycea Lucifuga*	$6.2x10^4$ (0.01)	$3.0x10^5$ (0.04)	$7.4x10^6$ (0.95)	7.8×10^6

Table 1: *An analysis of threat to species habitat due to increasing development*

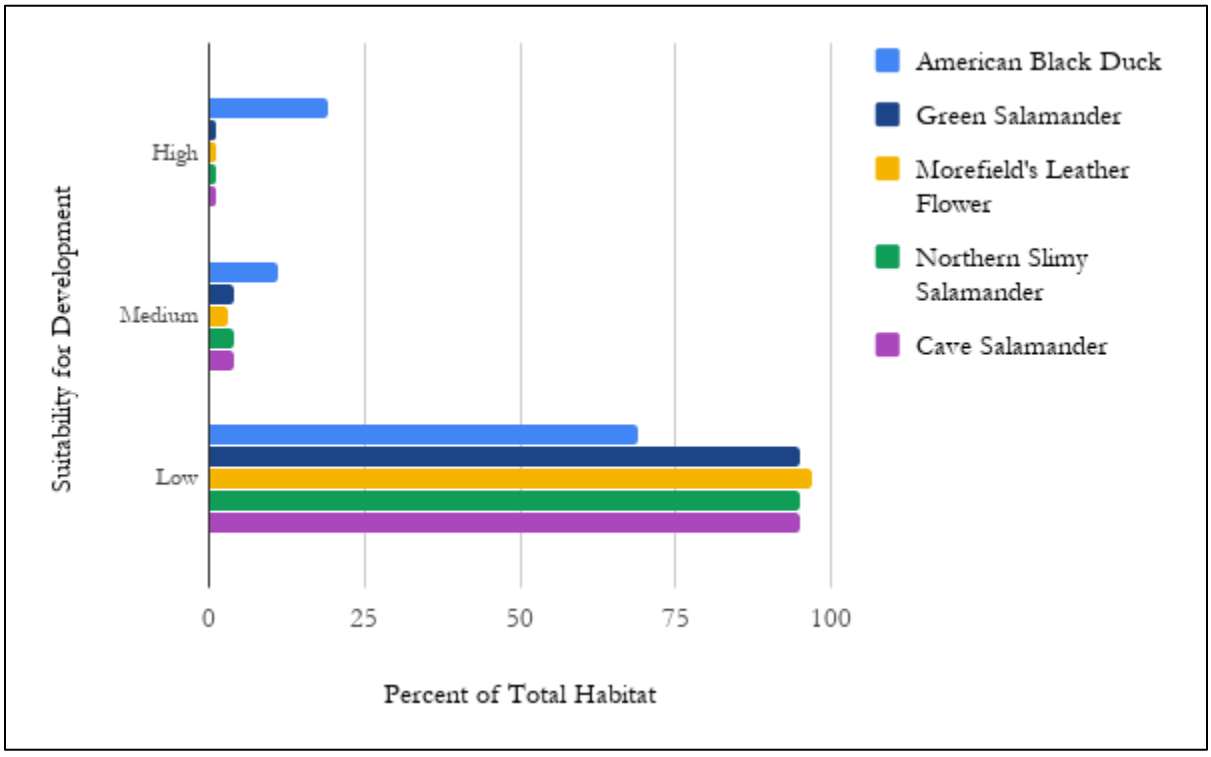


Figure 4: *Threat to species habitat due to suitability for urban development*

VI. Future Work

Incorporating a larger variety of species into the analysis would improve our understanding of the impacts of development. This project only assessed the impact of urbanization on selected species, but all species living in the areas facing development will be affected directly and indirectly. The species studied were chosen based on project partner interest and available data, but measuring the potential impact of urbanization on these few species may be misleading. If the impact is underestimated, further development could be extremely detrimental to species not included in this project. On the other hand, if the impact is overestimated, development may be impeded, resulting in lost profits for the county.

This study investigated urban development, but the transition of forest to agriculture is an important issue in North Alabama. Most of the endangered species in the study area are aquatic, such as clams, snails, and fish. Creating a hydrological model would more accurately portray the impact of urbanization on aquatic species. This model would provide a meaningful way to measure the estimated effects of potential runoff from new urban and agricultural development on aquatic species.

This project was designed around the Landsat series of satellites to gather a better understanding of the historical context of urbanization of north Alabama. Looking forward, this project could be conducted using Sentinel-2 data, with its higher spatial of 10 m to 60 m and 10 day return period.

VII. Conclusions

Habitat in Limestone and Madison counties is being replaced with urban and agricultural areas. Areas that are highly suitable for urban development are forecasted to be urbanized by 2045, with most of urbanization taking place in the areas located between Huntsville, Athens, and Decatur. Further agricultural development is expected to support these new urban areas. The American black duck, green salamander, Morefield's leather flower, northern slimy salamander, and cave salamander are all expected to be negatively impacted from increased urbanization. The species selected for this study were chosen based on partner interest and data availability. They include a large variety of species, somewhat representative of species native to north Alabama. Habitats for the American black duck that are negatively impacted by urbanization will also likely harm the habitats of other waterfowl species, such as the Whooping crane (*Grus americana*). Similar conclusions can be made for other salamander or plant species. The Land Trust of North Alabama works to conserve land and will be able to utilize the tool created during this project to help study the impact of urbanization on any potential species using location point data. The maps generated from this project, and future maps generated from the tool, will allow the Land Trust to educate local government officials and land owners on the potential negative impacts of urbanization on local species' habitats within Madison and Limestone counties. Ultimately, they will be able to identify areas where conservation efforts are needed.

VIII. Acknowledgments

Thanks to Marie Bostick (Executive Director, Land Trust of North Alabama), Andy Prewett (Land Manager, Land Trust of North Alabama), Hallie Porter (Development Director, Land Trust of North Alabama), Dr. Jeffrey Luvall (Science Advisor, NASA Marshall Space Flight Center), Dr. Robert Griffin (Science Advisor, University of Alabama in Huntsville), Leigh Sinclair (Mentor, University of Alabama in Huntsville/Information Technology and Systems Center), Maggi Klug (Alabama—Marshall Center Lead NASA DEVELOP), Mercedes Bartkovich (Alabama—Marshall Fellow, NASA DEVELOP), Dashiell Cruz (Alabama—Marshall Fellow, NASA DEVELOP), Andrew Cantrell (Alabama Agricultural and Mechanical University), Christine Easterwood (U.S. Army Garrison, Redstone Arsenal), Michael Barbour (Alabama Natural Heritage Program, Auburn University), and Rebecca John (Auburn University) for their contributions to this project.

This material is based upon work supported by NASA through contract NNL16AA05C and cooperative agreement NNX14AB60A. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Aeronautics and Space Administration (NASA).

References

Alabama Natural Heritage Program. (2016). *Alabama Natural Heritage Program Clematis*. [data file]. Auburn, Alabama. Alabama Natural Heritage Program.

Bilecki, L. C. (2003). Bat hibernacula in the karst landscape of Central Manitoba: protecting critical wildlife habitat while managing for resource development (Doctoral dissertation). University of Manitoba.

Bostick, M. (2017, October). Personal interview.

Cantrell, A**.** (MS, May 2011; Advisor Dr. Wang). Thesis: Herpetofaunal and Small Mammal Response to Oak Regeneration Treatments on the Mid-cumberland Plateau of Southern Tennessee (Master's thesis). Alabama A&M University, Normal, Alabama.

Hannon, S. J., Paszkowski, C. A., Boutin, S., DeGroot, J., Macdonald, S.E., Wheatley, M., & Eaton, B. R. (2002). Abundance and Species Composition of Amphibians, Small Mammals, and Songbirds in Riparian Forest Buffer Strips of Varying Widths in the Boreal Mixed Wood of Alberta. *Canadian Journal of Forest Research 32 (10)* 1784–1800. https://doi.org/10.1139/x02-092

Jarvis, A., Reuter, H.I., Nelson, A., & Guevara, E. (2008). *Hole-filled SRTM for the Globe Version 4* [Data file]. Retrieved from http://srtm.csi.cgiar.org

Jones III, E. B. D., Helfman, G. S., Harper, J. O., & Bolstad, P. V. (1999). Effects of Riparian Forest Removal on Fish Assemblages in Southern Appalachian Streams. *Conservation Biology 13 (6)*: 1454–1465.

John, R. (2017; Advisor Robert Gitzen). Movement, Occupancy, and Detectability of Green Salamander (*Aneides aeneues*) in Northern Alabama (Master's thesis). Auburn University, Auburn, Alabama.

Land Trust. (2017). Land Trust of North Alabama. Retrieved from http://www.landtrustnal.org/about

NatureServe. (2014). *Elassoma alabamae*. The IUCN Red List of Threatened Species 2014. Retrieved from http://dx.doi.org/10.2305/IUCN.UK.2014-3.RLTS.T202436A13482095.en

Ongley, E. D. (1996). Control of Water Pollution from Agriculture. *Food and Agriculture Organization irrigation and drainage paper, 55*. Retrieved from http://www.fao.org/docrep/w2598e/w2598e00.htm

Stein, B.A. (2002). States of the Union: Ranking America's Biodiversity. Arlington, Virginia: NatureServe.

U.S. Census Bureau. (2012). Alabama 2010: Population and Housing Unit Counts. Retrieved from https://www.census.gov/prod/cen2010/cph-2-2.pdf

U.S. Census Bureau. (2016). QuickFacts, Alabama. Retrieved from https://www.census.gov/quickfacts/fact/table/limestonecountyalabama/PST045216

U.S. Fish & Wildlife Service. (n.d.). Environmental Conservation Online System: Species Reports. Retrieved from https://ecos.fws.gov/ecp/species-reports

U.S. Geological Survey Earth Resources Observation and Science Center. (2012). Provisional Landsat TM Surface Reflectance [Data set]. U.S. Geological Survey. https://doi.org/10.5066/f7kd1vz9

U.S. Geological Survey Earth Resources Observation and Science Center. (2014). Provisional Landsat OLI Surface Reflectance [Data set]. U.S. Geological Survey. https://doi.org/10.5066/f78s4mzj

Wickham, J. D., Stehman, S. V., Gass, L., Dewitz, J., Fry, J. A., & Wade, T. G. (2013). Accuracy Assessment of NLCD 2006 Land Cover and Impervious Surface. *Remote Sensing of Environment*, 130, 294-304.

Crafting British Superiority:
A Study of Eighteenth and Nineteenth Century Cookbooks

Meg Bojarski
Department of History

Abstract **–** This paper explores the development of British culture through the foreign foods it scorned and appropriated during its imperialistic reign. This has been done through analyzing five British cookbooks from the eighteenth and nineteenth centuries, noting the presence and presentation of French cuisine, non-culinary recipes, and colonial foods. Based on this analysis, the paper argues that Britain crafted a sense of cultural superiority through their ability to consume foods from whichever countries they chose, denying the legitimate dependence they had on other countries for recipes and ingredients. This provides a new perspective on the rise of the British Empire, showing that an examination of food integration and description within cookbooks and other literature can provide historians with a stronger understanding of how national identity is created.

I. Introduction

Imperialism and competition between European powers made the creation of national identities necessary, though more difficult than it had been prior to globalization. Britain struggled with this, not having a well-defined culture to spread to their colonies or hold over their opponents. In the seventeenth and early-eighteenth centuries, Britain's upper classes tended to adopt French culture rather than practicing their own. Through accepting French culture, Britain created instability within its colonies. British colonizers craved French cuisine as much as they did their own. Why would their colonies accept British culture when their own people did not? To combat the idea of Britain as culturally subservient to France, Britain gave prominence to aspects of their colonies' cuisines that would demonstrate their global dominance. While successfully lessening the power of French culture, the adoption of colonial cuisines provided more ammunition to those who would point out Britain's lack of a strong culinary tradition of their own. Cookbooks trace this insecurity of identity and the strategies used to prove Britain's superiority. Authors used a variety of methods over the course of the eighteenth and nineteenth century to combat their cultural competitors, all with the intention of showing that, despite an obvious reliance on French cuisine and colonial resources, the ability to selectively accept or reject foreign cuisines proved their power. To explore that idea, this essay will analyze the presence of French cuisine, non-culinary British recipes, and colonial cooking, specifically Indian curry, in five cookbooks from 1750 to 1850: *The Art of Cookery* and *A New and Easy Method of Cookery* from the late eighteenth century, *Culina Famulatrix Medicinae* from the start of the nineteenth century, and *The Cook's Oracle* and *The Modern Cook* from the middle of the nineteenth century.

II. French Cuisine

The handling of French cuisine in eighteenth-century British cookbooks suggests an attempt to alleviate the culinary dissonance that was created by the consumption of the food, and thus culture, of an opponent. Despite a vocal rejection of French culture, the British people were accustomed to having access to French cuisine and expected cookbooks to contain at least some reference to the food that they preferred. It should be mentioned that the majority of citizens were not invested in French cuisine, as they were unable to afford it. The wealthy—the target audiences of most early cookbooks—were the primary consumers of French cuisine. Because of this, it was necessary for cookbooks to include French cuisine in order to establish credibility as knowledgeable cooks and cater to the desires of the wealthy, though French recipes were often highly Anglicized in ingredients and scorned by the authors. The Anglicization was most likely done out of practicality: it was difficult to have access to ingredients from a country that the British were at war with. The scorning held much deeper political motivations. John Thacker provides an excellent example of this practice, including both French bisques and Spanish olio (the Spanish were only slightly less hated than the French), yet stating in both the preface and the recipes themselves that

traditional British cuisines were far superior to the foreign recipes included.[1] It is no coincidence that this cookbook, straying from previous trends of exalting French cuisine, was published two years into the Seven Years War. The scorning of foreign cuisines was done to transition the appeal of such foods in the minds of the people, developing pride in national cuisines and attempting to eliminate the reliance on French cuisine in formal circumstances.

The introduction and proliferation of female authors helped to drive this transition, as female-authored cookbooks made the majority of disparaging comments towards French cuisine.[2] The increases in wealth and resources in the eighteenth century allowed for the wider production and consumption of literature, including cookbooks written by women who had extensive knowledge of cooking but were not seen as professionals because of their gender. These cookbooks were less highly esteemed, and thus were consumed more frequently by the middle and lower-middle classes. This audience was more willing to reject French cuisine because it was more expensive than they could afford on a regular basis. The transition of audiences and frequency of scorn successfully limited the honor given to French cuisine within British cookbooks. Elizabeth Cleland's *A New and Easy Method of Cookery*, published seventeen years after Thacker's book, was able to incorporate French cuisine again without active negative commentary due to five years of peace between the two nations. By this time, however, the damage had been done. While there were not frequent condemnations any longer, there was very little direct reference to French cuisine in cookbooks at all. By then, the idea that British cuisine was superior to French cuisine had been integrated into the structure of cookbooks and was not going anywhere anytime soon.

Cookbooks of the nineteenth century continued this assertion, promoting British superiority through their supposed ability to accept or reject aspects of international cuisine at their discretion. At the turn of the century, the technique of disparaging French cuisine continued to show up on occasion, though it blended with the emergence of a new tactic: not emphasizing French cuisine at all. This combined technique can be seen in one cookbook that complains at the unhealthiness of several dishes, even comparing a couple to Pandora's Box, yet does not even reference the recipes' French origins.[3] By scorning them, the author suggests that his readers not eat what is, in actuality, French cuisine. By not addressing them as such, the author denies the French their claim to the food and places himself in a position of power wherein he (and Britain, by extension) may claim the rights to any country's food and make it their own. As the century went on, many cookbooks did not bother to condemn French recipes at all, simply including them alongside other foreign recipes. This served to explicitly mark French cuisine as separate from British cuisine and to eliminate the image of superiority that it had held for so long. By placing French cuisine on the same level as Italian, Dutch, German, Russian, and even Polish cuisines, authors implicitly stated that French cuisine was in fact inferior, as their opinion of these other countries was not high. The inclusion of all of these different cuisines presented Britain as a country capable of sampling the world. In fact, a key recipe included in both *The Cook's Oracle* (1830) and *The Modern Cook* (1846) was a dish called "Poor Man's Sauce", specifically mentioned as a French reprieve from their usual excessive and rich fare.[4] This functioned as an attack on French superiority, as the dish's popularity seemed to prove that the French themselves disliked, or were overwhelmed by, their own cuisine. It also established that the British were able to choose the French recipes most suited to their own palates for consumption. No longer were they accepting another country's cuisine without scrutiny. Now, they chose what they wanted and rejected all else. The idea of superiority that the British constructed is challenged by looking at *The Modern Cook*, written by Queen Victoria's own cook, which includes bills of fare and lists of dinners prepared for the queen; these contained a much higher proportion

[1] John Thacker, *The Art of Cookery* (East Sussex: Southover Press, 2004), Preface, 239, 288.

[2] Elizabeth M. Schmidt, "Elegant Dishes and Unrefined Truths: A Culinary Search for Identity in Eighteenth-Century Britain," *Eighteenth-Century Thought* 6 (2016): 65-8.

[3] Ignotus, *Culina Famulatrix Medicinae*, ed. A. Hunter, 3rd ed. (York: T. Wilson and R. Spence, 1806), PDF, 51, 64-5.

[4] William Kitchiner, *The Cook's Oracle* (New York: J & J Harper, 1830), 243. Francatelli, *The Modern Cook* (New York: Dover Publications, 1973), 38-9.

of French dishes than the cookbook as a whole did.[5] The consumption of primarily French dishes by the Queen and other members of the upper classes showed that very little had changed in the actual practice of food consumption, though the idea of rejecting French cuisine had been deeply integrated into the literature.

Another tactic used by the British to eliminate the place for French recipes, particularly in female-authored cookbooks, was to simply change the purpose of the books from pure cookbooks to all-purpose guides for housekeepers and lower-middle class wives, including sections on beauty, cleaning, and medicine. Household literature was more readily accepted by the masses than British culinary recipes, both in Britain and in the wealthier households in the colonies. Because of this, the new integration of household recipes into cookbooks provided a way for British culture and cuisine to trickle into the colonies alongside the non-culinary recipes they likely acquired the book for. This is particularly true during the early integration of household recipes, which was done somewhat haphazardly, with little separation between culinary and non-culinary recipes. For example, Cleland's cookbook contains a chapter, "Of Wines &c", which contains recipes for all sorts of spirits as well as "Plague Water", face wash, medication, and more.[6] Those looking for a new face wash would flip through all of the alcoholic recipes before they found what they were looking for, and, with any luck, they would find something that caught their eye. Beyond this, middle class homeowners would typically acquire as few resources as possible to complete their required tasks. By combining cooking and household maintenance into one text, authors practically guaranteed that their cookbooks would be purchased. In addition to a true change in audiences, the shift to combining these books was made in an effort to present cookbooks as sources for the general populace, who were unlikely to make French cuisine because of the cost and time in preparation that it required.[7] This change in perceived audience allowed authors to leave out foreign dishes that might threaten British national identity and created some aspect of British culture that would be universally accepted. As time wore on and this technique became more deeply engrained in what a cookbook was understood to be, authors designated specific chapters to non-culinary recipes and advice for running a household. The tricks of integration were no longer necessary as developments towards "British cuisine" had already been made.

III. Colonial Cuisine

A major component of the new British cuisine was the presence of colonial recipes and ingredients alongside traditionally British meals. Despite the imperialistic insecurity that had been so overwhelming when the British looked at the French culture's impact on their meals, colonial recipes and ingredients were frequently promoted. Recipes for Irish stew were present in Kitchiner's *The Cook's Oracle*, and comparable meals, typically considered to be for the lower classes, were present in most nineteenth century cookbooks, though the specific colonial recipes and ingredients were varied enough that it would take a far longer study to analyze the full extent of colonial cuisine in British cookbooks.[8] Curry was the most common colonial recipe by far, occasionally placed alongside Anglo-Indian dishes such as Burdwan stew. Because of this frequency and the relatively universal acceptance of curry in British culture, it will be the primary focus of this section.

Where French cuisine was openly rejected yet widely eaten by the wealthy, curry and other colonial foods followed nearly the complete opposite path. The British people appeared to accept curry with overwhelming eagerness at the start of the nineteenth century. It had first become commercially available in London in 1784, during Company rule of India.[9] While this essay does not examine any sources closer to that time to see the immediate impact of curry on British society, it is worth noting that each of the cookbooks examined from the nineteenth century on has at least

[5] Francatelli, *The Modern Cook*, 513, 569. There is an entire chapter devoted to this concept, but these pages are particularly good examples.

[6] Elizabeth Cleland, *A New and Easy Method of Cookery* (Berwick upon Tweed: The Paxton Trust, 2005), 202-4.

[7] Anne Willan, Mark Cherniavsky, and Kyri Claflin, *The Cookbook Library* (Berkeley: University of California Press, 2012), 197-201.

[8] Kitchiner, *The Cook's Oracle*, 305.

[9] Susan Zlotnick, "Domesticating Imperialism: Curry and Cookbooks in Victorian England," *Frontiers: A Journal of Women Studies* 16 (1996): 59, doi:10.2307/3346803.

one recipe for curry, with *Culina Famulatrix Medicinae* containing an astounding eight curry recipes. Curry's presence in popular cookbooks was extremely widespread, but that does not mean its value is equivalent to what its frequency might suggest. Though *The Modern Cook* includes a recipe for "Indian curry sauce" and several other colonial products, it is worth noting that these products are not present in the book's Bills of Fare for formal dining at the Queen's feasts.[10] Curry was important to the construction of British culture but not consumed by the wealthy, which makes it clear that its popularity came not from the superiority of the food but because the government made it seem superior. Britain was no longer self-sufficient, having spread its resources towards creating an empire.[11] Cookbooks, advertisements, and the like were creating a demand for colonial goods because they were what Britain had the most access to. Thus, the frequency of colonial products in cookbooks points to a need to sell colonial products, the opposite of the suppression that French cuisine had garnered.

Britain was weakened by their imperialistic mission, but claimed that their acceptance of colonial meals was intentional and a show of power, a typically British spin on why their culture was so deeply reliant on other nations. The adoption of colonial cuisine was a complex issue to spin. If they were truly the superior culture, then it would seem as though they should be pushing their culture onto their colonies rather than adopting the traditions of the supposedly "inferior" peoples. Susan Zlotnick attempts to explain this contradiction as likely being due to "…ways in which the Victorians understood India to be theirs."[12] If India was part of the British Empire, they reasoned, then they had every right to claim whatever resources they found to be valuable. This argument is almost certainly the way by which the British government sold curry's sudden importance in their society, but it seems to be somewhat weak when the sheer strength of the arguments in favor of curry are examined. Unlike the treatment of European foreign foods, curry was either not expounded upon or heavily praised. The author of *Culina Famulatrix Medicinae* even goes so far as to counter arguments that presumably had been made in the past, claiming that "to those who are not in the habit of eating curry," the recipe may seem to be too spicy or too highly seasoned, but in fact only tastes too heavily seasoned when the consumer does not appropriately combine the curry with rice.[13] While the majority of the arguments against the French were as a result of their overwhelming flavor, curry was seen highly enough that British consumers, who had been praised in other portions of this book, were told that if they found curry unpalatable, they were uneducated. This comment shows just how strongly curry was being pushed; the author was willing to almost explicitly state that those accustomed to Indian food were superior to those who were not. The force of this claim and others like it show that those in power had a vested interest in the integration of curry and other colonial products into the larger British identity.

IV. Conclusion

When Britain began its imperialistic mission, it did not have much of a culinary culture of its own to share with its colonies. Instead, Britain created a societal understanding of superiority that came not from having a superior culture, but rather from having the power to claim the cultures of those who were more clearly developed. This excuse, and its diffusion into popular society, was present in the subtle messages of cookbooks that claimed that the reader, as a British citizen, was above all others. Through this examination, the insecurity and development of national identity in Britain can be seen from a new angle that clearly presents both the ideal and the actual British identity. The history of cultural construction is difficult to trace, as it is infrequently mentioned directly in sources. The examination of cookbooks and other sources intended for the consumption of contemporaries provides an excellent methodology to study ideological shifts, a methodology which is crucial to the furthering of the field as a whole.

[10] Francatelli, *The Modern Cook*, 44.
[11] Thomas Prasch, "Eating the World: London in 1851," *Victorian Literature and Culture* 36, no. 2 (2008): 589, http://www.jstor.org/stable/40347206.
[12] Zlotnick, "Domesticating Imperialism," 64.
[13] Ignotus, *Culina Famulatrix Medicinae*, 166.

References

Cleland, Elizabeth. *A New and Easy Method of Cookery*. Berwick upon Tweed: The Paxton Trust, 2005.

Francatelli. *The Modern Cook*. New York: Dover Publications, 1973.

Ignotus. *Culina Famulatrix Medicinae*. Edited by A. Hunter. 3rd ed. York: T. Wilson and R. Spence, 1806. PDF.

Kitchiner, William. *The Cook's Oracle*. New York: J & J Harper, 1830.

Prasch, Thomas. "Eating the World: London in 1851." *Victorian Literature and Culture*36, no. 2 (2008): 587-602. http://www.jstor.org/stable/40347206.

Schmidt, Elizabeth M. "Elegant Dishes and Unrefined Truths: A Culinary Search for Identity in Eighteenth-Century Britain." *Eighteenth-Century Thought*6 (2016): 61-81.

Thacker, John. *The Art of Cookery*. East Sussex: Southover Press, 2004.

Willan, Anne, Mark Cherniavsky, and Kyri Claflin. *The Cookbook Library*. Berkeley: University of California Press, 2012.

Zlotnick, Susan. "Domesticating Imperialism: Curry and Cookbooks in Victorian England." *Frontiers: A Journal of Women Studies*16 (1996): 51-68. doi:10.2307/3346803.

An Investigation of Copper Catalysts for Propylene Epoxidation

Hayden Fowler
Department of Chemical and Materials Engineering

Abstract – The industry for propylene oxide (PO) is in need of a more efficient, environmentally-friendly method of PO production. This study is focused on optimizing conditions for the gas-phase epoxidation of propylene with molecular oxygen in a single step over Cu catalysts for use in future research involving Au-Cu bimetallic catalysts. To do this, a 5 wt% Cu/SiO_2 catalyst was prepared using incipient wetness impregnation and tested over a temperature range of 220-300 °C, varying the flow rate and ratio of reactants. Lower total flow rates led to higher conversions, and using excess oxygen favors complete combustion of propylene to CO_2. As temperature was increased, conversion and CO_2 selectivity were increased, and PO selectivity was decreased. These conditions will be used to design future Au-Cu bimetallic catalyst testing parameters.

I. Introduction

Propylene oxide (PO) is a very highly-valued chemical intermediate, produced at a rate of 8 million tons per year with a price of $2,500 per ton, making PO production a $20 billion industry [1]. PO is used to synthesize other chemicals and polymers, such as propylene glycols, polyurethane, and polyether polyols [2]. These products are in turn used for a variety of applications, including the automobile, construction, pharmaceutical, and cosmetics industries. Products like polyurethane foams and polyester resins are largely made possible by PO [2].

All current industrial methods for producing PO occur in multiple steps in the liquid phase. This requires separation processes for retrieving PO from other reaction products. Because of this, the cost and energy requirements of production plants is greatly increased. Furthermore, the most popular industrial methods of PO production are the chlorohydrin and hydroperoxide coproduct processes, accounting for 91% of commercial PO production in total [3]. Both methods produce an excessive amount of unwanted byproducts. The chlorohydrin process produces 2.2 tons of $CaCl_2$ salts per ton of PO, along with toxic, chlorinated, organic compounds at a much smaller amount, making this method overwhelmingly wasteful and environmentally harmful [3]. The hydroperoxide coproduct process produces useful byproducts; however, their production is much greater than demand, being produced at two to three times the amount of PO [3].

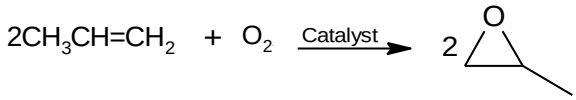


Figure 1: *Propylene reacts with molecular oxygen over a catalyst to give propylene oxide. This method would be a beneficial alternative to current industrial methods.*

Industrial production of PO has major downfalls, including being wasteful, expensive, inefficient, and environmentally harmful. The PO industry and the environment would greatly benefit from a more efficient, environmentally-friendly method of PO production. One possible alternative is the gas-phase epoxidation of propylene by molecular oxygen in the presence of a catalyst, as shown in **Figure 1** [3]. This method, occurring in a single step, would greatly lessen the amount of equipment needed in plants, resulting in lower costs and energy usage. Due to the greater efficiency, PO could be produced in larger amounts at lower prices, allowing for more PO production plants to open and for more jobs to be created. When the gas-phase reaction is optimized, the only byproduct is water, making this method non-wasteful and environmentally friendly. Therefore, optimizing this method for industrial use would improve, if not eliminate, all current problems seen in current industrial methods.

Au-Cu bimetallic catalysts could be the answer to this alternative method of production. Bimetallic catalysts offer a promising method for combining the best qualities of two metal catalysts.

Many investigations have been done using coinage metals, i.e. Au, Ag, and Cu, as the catalyst for this reaction [1,4]. The current benchmark catalyst for this reaction is Au, reaching selectivity for PO near 100% [1]. However, the conversion of propylene to PO is low, and Au is expensive. Evidence exists to suggest that Cu may provide better conversion than Au and a better selectivity than Ag [1,5]. Compared with Au, non-precious metal Cu offers an inexpensive, earth-abundant alternative. However, the selectivity of the reaction for PO from Au is still superior. Therefore, it is of great interest to produce a bimetallic Au-Cu catalyst to increase the conversion of propylene while maintaining the high selectivity offered by Au alone.

Before beginning this research, it would be beneficial to fully understand the performance and behavior of Cu catalysts for the reaction. While Au catalysts are mostly understood, Cu catalysts may operate optimally at completely different conditions for this reaction. This may include a different temperature range, amount of copper present, flow rate of reactants, or even ratio of reactants present. A better understanding of how monometallic Cu catalysts work will provide greater insight when designing bimetallic Au-Cu catalysts later, especially when considering reaction conditions and relative amounts of each metal present.

The purpose of this study was to optimize the conditions for the reaction of propylene with molecular oxygen over Cu catalysts. This work was based on Lambert's research on Cu catalysts for propylene epoxidation, and a comparison was done with Lambert's work accordingly [7]. The conditions to be optimized were total flow rate of reactants, ratio of propylene to oxygen, and temperature. Furthermore, characterization was done on the catalyst in order to understand the function of Cu catalysts for the reaction. The data and conclusions obtained from this study will be used when designing future experiments involving the testing of Au-Cu bimetallic catalysts.

II. Experimental

Catalyst Preparation

A 5 wt% Cu/SiO_2 catalyst was prepared using incipient wetness impregnation (IWI). 100 mL of a $Cu(NO_3)_2$ precursor solution was created by dissolving $Cu(NO_3)_2{\cdot}3H_2O$ (Sigma Aldrich, 61197) in deionized water to give a 0.118 g $Cu(NO_3)_2{\cdot}3H_2O$/mL solution. 4.845 mL of precursor solution was deposited onto 2.85 g of SiO_2 via pipette. The catalyst was dried in static air at atmospheric pressure for 10 hours at 120 °C. The catalyst was then calcined in flowing air (50 mL/min) at 300 °C for 4 hours. The catalyst was pressed and sieved to a grain size of 180-250 μm. Prior to testing, the catalyst was reduced in 5% H_2 in Ar (total flow: 25 mL/min) for 1 hour and at 300 °C. The reduction of the Cu species in the catalyst is done to remove oxygen from the surface of the catalyst prior to reaction of propylene with oxygen. The reduction yields water from combining hydrogen and oxygen at the surface.

Catalytic Reaction

100 mg of catalyst was diluted by 1 g of quartz and loaded into a glass tube to create a packed bed reactor. The reactor was placed into a furnace to allow for temperature control. The flow rates of reactant and carrier gases were varied to determine the effects of flow rates and ratios on the catalytic performance.

The catalyst was tested at the following conditions on a temperature range of 220-300 °C:

- 5% O_2, 5% C_3H_6, balanced in Ar at a flow rate of 50 mL/min
- 5% O_2, 5% C_3H_6, balanced in Ar at a flow rate of 20 mL/min
- 5% O_2, 10% C_3H_6, balanced in Ar at a flow rate of 20 mL/min

The catalyst testing system is shown in **Figure 2**. The products of reaction were identified and the relative amounts measured using gas chromatography via HP 5890 Series II gas chromatograph. Using these relative amounts, the conversion of propylene and the selectivity for each product were calculated via equations 1 and 2.

$$(1)\quad \text{Conversion} = 1 - \frac{\begin{pmatrix}\text{Amount of propylene}\\ \text{present after reaction}\end{pmatrix}}{\begin{pmatrix}\text{Amount of propylene}\\ \text{present before reaction}\end{pmatrix}}$$

$$(2)\quad \text{Selectivity} = \frac{\begin{pmatrix}\text{Amount of PO}\\ \text{present}\end{pmatrix}}{\begin{pmatrix}\text{Amount of total}\\ \text{products present}\end{pmatrix}}$$

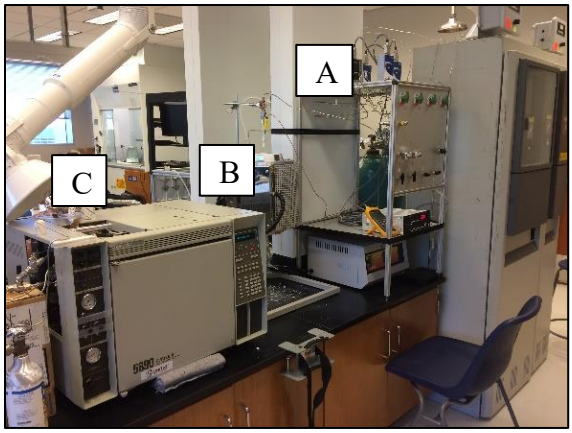


Figure 2: *The catalyst testing system consists of mass flow controllers* (A), *reactor and furnace* (B), *and gas chromatograph* (C).

Catalytic Characterization

X-Ray diffraction (XRD) analysis was performed on the catalyst before and after reaction using a Rigaku MiniFlex 600 X-ray diffractometer.

III. Results and Discussion

XRD Characterization

XRD of 5 wt% Cu/SiO_2

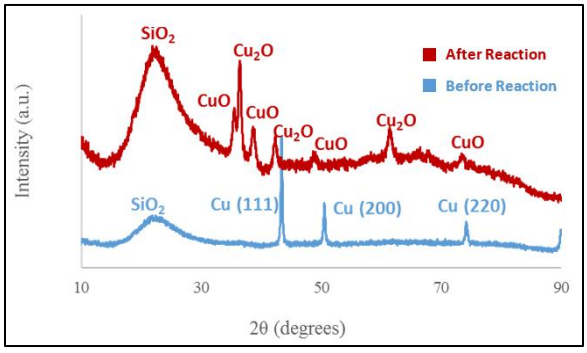


Figure 3: *The XRD spectra of the catalyst were taken before (blue) and after (red) reaction. Before reaction, the peaks are consistent with unoxidized Cu, while after reaction, peaks indicate the presence of* Cu^+ *and* Cu^{2+}.

The XRD spectra taken before reaction of propylene and oxygen to PO, shown in Figure 3, are consistent with SiO_2 and Cu^0. This indicates that Cu^0 is the only present oxidation state of Cu prior to reaction and that the copper species in the catalyst were completed reduced by H_2.

After the reaction, as shown in Figure 3, the spectrum changes significantly, indicating a change in present species. Upon further analysis, it was determined that the new peaks are consistent with the Cu^+ and Cu^{2+} oxidation states. Copper is oxidized easily, and given that molecular oxygen was used as a reactant, these results were consistent with the literature [6,7].

Catalytic Performance

The observable products of reaction were PO, CO_2, acrolein, ethanal, and acetone. Of these, CO_2 and acrolein were major, and PO was of interest. These were the major products noted in the literature as well [5]. Due to the minimal amounts of ethanal and acetone being produced, these byproducts will not be discussed further in this report.

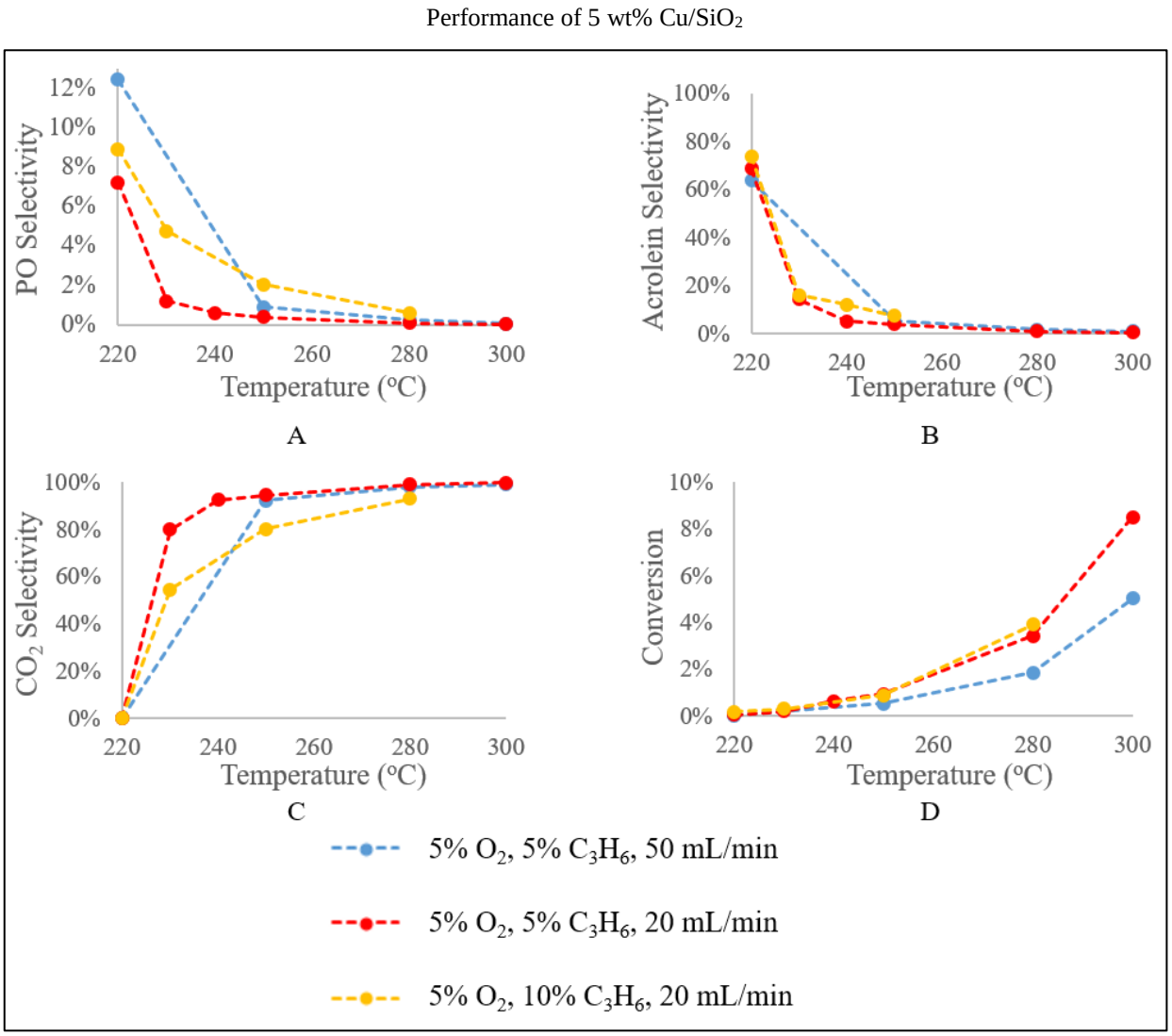


Figure 4: *The data are presented from the tested scenarios: 5% O_2/5% C_3H_6/ 90% Ar at 50 mL/min* (●), *5% O_2/5% C_3H_6/ 90% Ar at 20 mL/min* (●), *and 5% O_2/10% C_3H_6/ 90% Ar at 20 mL/min* (●). (A) *The selectivity of the reaction for PO decreases significantly as temperature increases. A greater flow rate for a 1:1 ratio of propylene to oxygen gives a higher selectivity. However, a 2:1 ratio of propylene to oxygen at a lower flow rate performs better for PO selectivity over the entire temperature range.* (B) *Acrolein is a major product for the lowest temperature in the range for each scenario. As temperature increases, selectivity for acrolein decreases similarly for each scenario.* (C) *Above temperatures of 220 °C, CO_2 becomes the dominant product of reaction, reaching selectivity of around 90% for higher temperatures. Decreasing the flow rate and providing a more stoichiometric 2:1 ratio of propylene to oxygen significantly hinders CO_2 production for lower temperatures.* (D) *Conversion of propylene increases as temperature increases but does not light off within this temperature range. Lower flow rates give better conversions, but changing the ratio of propylene to oxygen has a small effect.*

Effect of Temperature

For each case tested, temperature has a major effect on the conversion of propylene and the selectivity for certain products of reaction. As shown in **Figure 4A and 4B**, as temperature is increased, the selectivity of the reaction for PO and acrolein is decreased significantly. The opposite is true for selectivity of the reaction for CO_2, as it increases with increasing temperature, as shown in **Figure 4C**. Conversion also increases with increasing temperature, as shown in **Figure 4D**. However, the conversion curves for each case do not light off within this temperature range. This is in good agreement with Lambert's work, in which conversion curves also do not light off within this temperature range [7].

From this data, it appears that at lower temperatures where PO selectivity is higher, conversion is very small, and vice versa. Higher temperatures drive the reaction towards combustion of propylene to generate more CO_2. This effect is also present in the literature [7,8,9]. Therefore, this catalyst alone would not be suitable for propylene epoxidation. However, combining Cu with Au and operating at a higher temperature could potentially increase the conversion of reaction while maintaining high selectivity. Since the reaction with Au will differ, an optimal temperature range for the bimetallic catalyst will need to be found. This temperature range can serve as the maximum consideration of temperatures, assuming Au follows the same pattern of decreasing PO selectivity with increasing temperature.

Effect of Flow Rate

From **Figure 4A**, it is shown that PO selectivity decreases when the total flow rate is decreased from 50 mL/min to 20 mL/min while maintaining a 1:1 ratio of propylene to oxygen. However, the selectivity for CO_2 and acrolein do not appear to be affected by the decrease in flow rate. Conversion behaves opposite of PO selectivity, increasing when the total flow rate is decreased from 50 mL/min to 20 mL/min maintaining a 1:1 propylene to oxygen ratio.

These trends can be explained by the residence time of reactants in the catalyst bed. A higher flow rate should give a lower residence time. Lower residence times may also mean less time for the reactants to be converted into products. Therefore, by this logic, an increase in flow rate, resulting in a decrease in residence time, should result in a lower conversion, and vice versa for a decrease in flow rate. This is shown by the data in **Figure 4**.

Effect of Reactant Ratios

Figure 4A shows that changing the ratio of propylene to oxygen from 1:1 to 2:1 has a significant effect on the selectivity of the reaction to PO while maintaining a constant total flow rate of 20 mL/min. This is true for the entire temperature range. Likewise, from **Figure 4C**, the selectivity of the reaction to CO_2 is decreased with this change in ratio. **Figure 4D** does not indicate a major change in conversion with this ratio change within this temperature range. **Figure 4B** could show a slight increase in acrolein selectivity with this ratio change, but the effect does not appear to be major.

This phenomenon is best explained by the stoichiometry of the reaction, shown in **Figure 1**. This reaction shows a 2:1 ratio of propylene to oxygen to give PO. **Figure 4A and 4C** show that the change in ratio from 1:1 to 2:1 leads to an increase in PO and decrease in CO_2. This indicates that a more stoichiometric ratio of reactants favors partial oxidation of propylene to PO, while an excess of oxygen favors complete combustion of propylene to CO_2.

A similar effect can be seen in literature; a decrease in the partial pressure of oxygen led to a decrease in CO_2 production [10]. However, in the case of this work, it resulted in more acrolein production, which was the reaction of interest. In this study, the selectivity towards acrolein is also increased when the ratio of propylene to oxygen is increased. Therefore, it can be concluded that partial oxidation to either acrolein or propylene is favored over complete combustion to CO_2 with more stoichiometric feeds.

Comparison with Lambert

Comparison of 5 wt% Cu/SiO_2 with Lambert's Catalyst

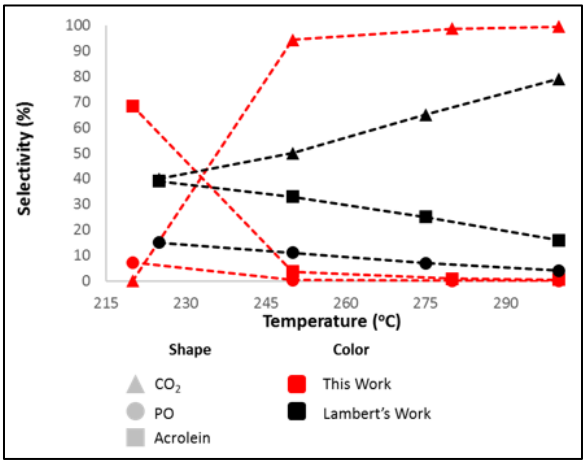


Figure 5: *A comparison of the data from this work and Lambert's work is given for the selectivity of major observed products. Both catalysts were prepared similarly and tested under similar conditions. The general trends for selectivity are the same for both works. However, this work's catalyst has a greater selectivity for CO_2, especially as higher temperatures.*

The preparation of the 5 wt% Cu/SiO_2 catalyst by IWI was largely inspired by a similar catalyst prepared in Lambert's work [7]. A comparison between the two catalyst performances with regards to the production of major products is shown in **Figure 5**. The trends of major product selectivity vs. temperature were similar for both catalysts. However, the amount of product formed in each case was drastically different, especially in the case of Acrolein and CO_2. The catalyst of this work produced significantly more CO_2, and CO_2 production increased much more rapidly earlier in the temperature

range. Lambert's catalyst produced much less CO_2 at a more linear relationship to temperature.

Furthermore, at 220 °C, no CO_2 was detectable, and the selectivity for Acrolein was higher than that of Lambert's. One possible explanation for this is the limits of the GC used in this experiment. CO_2 may have been present but not able to be detected. Otherwise, CO_2 production for this catalyst has a very strong dependence on temperature.

Overall, Lambert's catalyst performs better for PO selectivity, while the catalyst of this work largely favors combustion to CO_2. Changing the ratio of propylene to oxygen helped to decrease this effect. However, more solutions could be attempted from here, including adding a promoter or changing the support.

IV. Conclusion

The results of this study will provide a guideline for testing the conditions of future Cu-containing catalysts, particularly Au-Cu bimetallic catalysts. The goal is to use Cu to increase propylene conversion while maintaining high selectivity for PO offered by Au. Therefore, from these results, decreasing flow rate and providing a stoichiometric ratio of reactants will be considered for future Cu catalyst testing. Using higher temperature will also be considered for increasing conversion. However, the reaction temperature will also be largely dependent on the reaction conditions needed for Au catalysts. In general, trends have been established for temperature, flow rate, and reactant ratios with respect to selectivity and conversion. Therefore, a baseline for adjustments for future catalyst testing has been established.

V. Acknowledgments

This work is sponsored by the National Science Foundation (Grant # CBET-1511820 and CBET-1510485). H.F. specifically acknowledges the support from NSF-REU Supplemental Award, the Prevost Research Program Award, and the College of Engineering Undergraduate Research Program at the University of Alabama in Huntsville.

References

[1] Huang, J.; Haruta, M. Gas-phase Propene Epoxidation over Coinage Metal Catalysts. *Res Chem Intermed.* **2012**, 38, 1-24.

[2] Trent, D. L. Propylene Oxide. *The Dow Chem Co*. **1999**.

[3] Khatib, S. J.; Oyama, T. Direct Oxideation of Propylene to Propylene Oxide with Molecular Oxygen: A Review. *Catal Rev.: Sc. & Eng.* **2015**, 57, 1-39.

[4] Lei, Y. et al. Increased Silver Activity for Direct Propylene Epoxidation via Subnanometer Size Effects. *Science*. **2010**, 328, 224-228.

[5] Torres, D. et al. Why Copper is Intrinsically More Selective than Silver in Alkene Epoxidation: Ethylene Oxidation on Cu(111) versus Ag(111). *J Am Chem Soc.* **2005**, 127, 10774-10775.

[6] Yang, L. et al. Copper-catalyzed Propylene Epoxidation by Oxygen: Significant Promoting Effect of Vanadium on Unsupported Copper Catalyst. *J Catal.* **2010**, 276, 76-84.

[7] Vaughan, O. P. H. et al. Copper as a Selective Catalyst for the Epoxidation of Propene. *J Catal.* **2005**, 236, 401-404.

[8] Su, W. et al. A Molecular Insight into Propylene Epoxidation on Cu/SiO_2 Catalysts using O_2 as Oxidant. *J Catal.* **2009**, 268, 165-174.

[9] He, J. et al. Active Site and Reaction Mechanism for the Epoxidation of Propylene by Oxygen over CuO_x/SiO_2 Catalysts with and without Cs^+ Modification. *J Catal.* **2013**, 299, 53-66.

[10] Tuysuz, H. et al. Highly Diluted Copper in a Silica Matrix as Active Catalyst for Propylene Oxidation to Acrolein. *Catal Lett.* **2009**, 131, 49-53.

Measuring the Effects of the Alexander Technique on Posture and Tension in Student Violinists and Violists

Rebekah Frederick
Department of Mechanical and Aerospace Engineering / Department of Kinesiology

Abstract **–** Musicians often experience overuse injuries due to the repetitive movements they must use to play an instrument, and poor or unbalanced posture can contribute to pain and the likelihood of injury. The purpose of this study is to investigate the effect of the Alexander Technique (AT), a method to improve postural imbalances. Using motion capture technology, violinist and violists were tracked by motion-capture cameras that recorded their movement as they played. The participants played a short etude, watched an instructional video on the AT, and then applied the AT while replaying the same etude. The angular displacements of the head, neck and shoulders, were measured to quantify changes in body posture. There was a statistically significant difference between the pre- and post-AT measurement of the mean distance between the reflective markers placed at the mandibular angle (M = 149.39 SD = 16.74) and acromion process (M = 154.16, SD = 18.88), (t = 4.36, p = .01). There was no statistically significant difference between the pre- and post-AT measurement of the mean distance between the reflective markers placed at the C3 spinous process (M = 117.96, SD = 17.08) and the occipital bone (M = 126.5, SD = 11.36), (t = 2.02, p = .30). However, the mean distance was larger in three of the four participants. The results of this preliminary, pilot study indicated that the AT produced a measurable change in the potential to reduce the amount of tension and influence the unconscious postural habits that violinists and violists experience.

I. Background

Music is a universal language understood by all and it allows those who play instruments to develop and convey a form of self-expression and skill that applies to multiple areas of life. Through developing proficiency of concentration, fine motor skills, and efficient learning techniques within the experience of an art form, those who play instruments gain valuable life skills. However, playing a musical instrument can be a lead cause of injuries among instrumentalists and many of these injuries can go unseen until a physician's expertise is pursued. Musicians often experience overuse injuries due to the repetitive movements they must use to play an instrument, and poor or unbalanced posture can contribute to pain and the likelihood of injury.

While musicians are recognized as artists, they must also be considered athletes with the use of their fine motor skills and long hours of repetitive movement. At some point in an athlete's life, they will experience pain or discomfort due to their sport. Generally, there are measures in place for athletes to verbalize these issues and receive necessary treatments. However, according to a study by Rickert, Barret, and Ackermann (2015), student musicians in particular may be prone to demonstrating poor health awareness and verbalization of pain if it is experienced. Failing to bring up practice-related pain has the potential to lead to overuse injuries that can jeopardize a musician's future ability to play. Such overuse injuries are determined by pain in tendons, joints, ligaments, and muscles. Additionally, tissue damage can also occur from constant use over time due to poor posture, playing style, or lack of professional instruction.

Common Musician Injuries

While it is commonly expected that athletes will likely sustain injuries of some kind during training or games, the same expectation is generally not extended to student musicians. In an article by Ackerman and Chan (2014) on physical therapy for musicians, the authors note that while sports medicine focuses actively on making sure athletes are watched closely for injury and given strong medical support networks, there is little equivalent support for musicians.

Common musician injuries include a variety of muscular and neurogenic components and involve joints, tendons, muscles, and ligaments. Posture, playing style, and biological traits also play a factor in the characteristics that can determine injury susceptibility. From the neurogenic side, tendonitis and nerve compression are two common types of musician injury. Tendonitis occurs when tendons become inflamed due to muscle overuse. The resulting pain can seriously compromise a musician's ability to play and can persist at rest or in motion. Additionally,

tendonitis can be experienced at a single site, or spread throughout several physical locations. Trigger finger is a specific form of tendonitis that affects the palm and fingers, while De Quervain's Disease is an inflammation that occurs at the base of the thumb (Lukomski, 2004).

Nerve compression injuries can be caused by body structure and/or incorrect posture and generate weakness around the compression site along with numbness or tingling. Carpal tunnel syndrome, Pronator Teres Syndrome, Wartenburg Syndrome, Bowler's Thumb, Flexor Tenosynovitis, and Guyon's Canal Syndrome all fall under nerve compression injuries that musicians can be at risk for (Lukomski, 2004). Carpal tunnel causes a numbness and tingling on or around the thumb, ring finger, middle finger, and index finger, and cubital tunnel syndrome produces tingling pain at the inner elbow, particularly when bent. Thoracic Outlet Syndrome involves hand or arm fatigue, coldness, tingling, pain, and discoloration of the hand. Pronator Teres Syndrome leads to weakness and pain down the wrist and the hand, while Wartenburg Syndrome is indicated by numbness and pain on the outside of the wrist and the side of the thumb (Lukomski, 2004). Flexor Tenosynovitis presents with numbness of the median fingers during and immediately after playing. Bowler's thumb causes numbness and tingling of the thumb, while Guyon's Canal Syndrome can lead to weakness and decreased sensation of the pinky and ring finger (Lukomski, 2004).

In addition to the physical complications that may arise from playing a musical instrument, there are psychological complications that may exacerbate the likelihood of a musician developing an injury. In a study conducted by Rickert, Barret, and Ackermann (2015), student cellist majors at a New Zealand college were surveyed to gauge their injury awareness in relation to their instrument. The authors found a strong indication that the student musicians possessed poor health awareness and were unlikely to pay attention to their injuries when contrasted with their professional counterparts (Rickert et al., 2015). Many of the student cellists indicated that pain was something they simply dealt with. One piano/cello student admitted to experiencing pain when playing but then going so far as to say that he was still able to continue with twelve hours of rehearsals per day, demonstrating a troubling indifference to his physical pain signals (Rickert et al., 2015).

Common Violinist Injuries

For violinists and violists, pain signals are important as injury can lurk in both general and specific areas. Playing a violin or viola requires fine motor skills and repetitive movement of specific muscles. In a study by Hagberg, Thiringer, and Brandstrom (2005), neck, shoulder, elbow, and forearm pain was found to be more predominant in violinists and violists than it was in pianists. For violinists and violists, upper extremities including neck, shoulder and joints in the jaw are often affected first because of the head and shoulders being flexed for a prolonged period during playing (Nymann et al., 2007). Beyond general arm and shoulder discomfort, elbows and fingers were also found to be common sites of injury in musicians (Atunes & Moraes, 2012). These findings indicate that extensive playing time and/or unnatural posture from the position of a musical instrument can lead to both general and specific injuries to musicians at large.

For musicians, body position and posture are integral components to music-making. Musicians and their instruments must be, as noted by Atunes and Moraes (2012), analyzed for best postural alignments, ergonomics, and optimal positions of neck and hand. The long rehearsals that violinists and violists often sit through requires them to find appropriate body positions and frequently shift balance to maintain the best motor control possible during performances (Nymann et al., 2007). The most commonly seen injury, however, was found to be overuse (Fry, 1988). In the same review study conducted by Atunes and Moraes (2012), the conclusion reached was that in addition to overuse, focal dystonia and nerve compressions were the main disorders found, and that pain was the number one symptom. More specifically, Thoracic Outlet Syndrome was reported in 20% of the musicians studied, overuse in 50% of musicians, and focal dystonia in 10% of musicians (Foxman & Burgel, 2006). The repetitive movement of playing a musical instrument and poor posture from prolonged sitting and carrying instruments is thought to be the predominant contributor to these conditions (Moraes & Atunes, 2012).

The Alexander Technique

There are several treatment options available for musician injuries: preventative measures, occupational therapy, and mindfulness models such as the Alexander Technique all offer promising results. The AT offers musicians a method of changing their posture starting from a very basic level and allows those changes to transfer into the way a musician plays their instrument. This technique is a method of movement that is designed to bring heightened awareness to the way a person holds their body and aims to train the user to align their posture without unconscious or unnecessary muscular compensation.

The AT is described by authors Mayers and Babits (1987) as a re-training program to create mindfulness and to change inefficient movements that people make out of unconscious habit. The AT is not a stretching or relaxation technique such as yoga, nor a strengthening program such as Pilates, but rather a system of movement to promote efficient use of posture through using muscles embedded around the spine that are naturally designed to carry the head and back in an upright position. Throughout the course of a person's life, it is likely they will adapt to a pattern of movement that is unnatural but be unaware of their poor posture and assume their movements are normal and upright (Mayers & Babits, 1987).

There are three parts to the AT: developing an awareness of the physical state of the body, developing the ability to consciously refuse to respond to a situation with inefficient habits, and teaching a "direction" technique that communicates to the student how to use precise mental instructions to move the body with purpose and intention to maintain optimum balance of all body parts (Mayers & Babits, 1987). Peterson (2008) notes the biomechanical nature of the AT, relating that it zeroes in on the spine and skeleton, especially the cervical spine, and focuses on the most basic of movements. Even unconscious habits like standing up out of a chair are found to be fraught with potential physical problems when looked at more closely. In this research study, the use of the AT with the added ability to see in real-time how participant's posture responded through motion-capture technology has the potential to offer never-before-seen insights into the body mechanics of musicians.

Motion Capture Technology and Musicians

How then is it possible to detect postural imbalances that musicians themselves may not even recognize? Motion-capture technology, famous for its use in creating special effects for films, may offer a solution to this question. While studies have been conducted that observe a musician's performance through the use of motion capture technology, no studies have yet been pursued that focus on using this technology to detect and correct postural imbalances.

Motion-capture cameras allow researchers to detect postural changes musicians may experience as they play that would be nearly impossible to discern with the naked eye. This approach uses a system of cameras to track small, body-fixed markers that reflect near infrared light, allowing the cameras and computer software to "capture" the movements of these points on a musician's body to a high spatial resolution – within a few millimeters. Harnessing the capabilities of this technology offers the potential to definitively measure the movements of a musician and offer insight into developing tangible solutions for instrumentalists struggling with postural pain or imbalance.

Various exploratory studies exist on motion-capture technology and how it relates to studies with musicians. One study used the technology to measure the force of clarinetist's finger strokes (Palmer et al., 2009). Another study used motion-capture to track the movement of dancers and athletes and render still-frame images of what those motions looked like (Shan et al., 2010). An additional study researched the eigenmodes of music-induced movement to measure differences in joint movement when participants were asked to play an excerpt at three different speeds (Toivianinen, Luck, & Thompson, 2010). All studies used motion-capture cameras and reflective markers affixed to the participants to track the subject's movements.

Musician injury is an area of developing study, and while good sources are available for review, awareness in this area is not nearly as high as it is in the area of sports or other lifestyle activities that require fine motor movement or repetitive motion. The findings presented here give detail into the rationale of experiment parameters to include motion-capture software and the AT.

II. Purpose

The purpose of this study is to be able to identify the posture that musicians may experience firstly from their instructional experience, and secondly from a method such as the AT to observe and compare the postures of the violinist and violist participants by tracking specific anatomical landmarks (represented in **Figure 1**) with the motion-capture cameras to see if the AT training produced any measurable postural changes. The hypothesis proposes that the distance between the left jaw (mandibular angle) and left shoulder (acromion process) would increase after practicing the AT; this would indicate a lower, more relaxed position of the shoulder in relation to the chin. Similarly, it is hypothesized that the distance between the back, lower left head (occipital bone) and upper spine (C3 spinous process) would decrease following AT practice, further demonstrating a more relaxed playing position. A secondary hypothesis is that self-reported pain, tension, and focus would improve following AT practice.

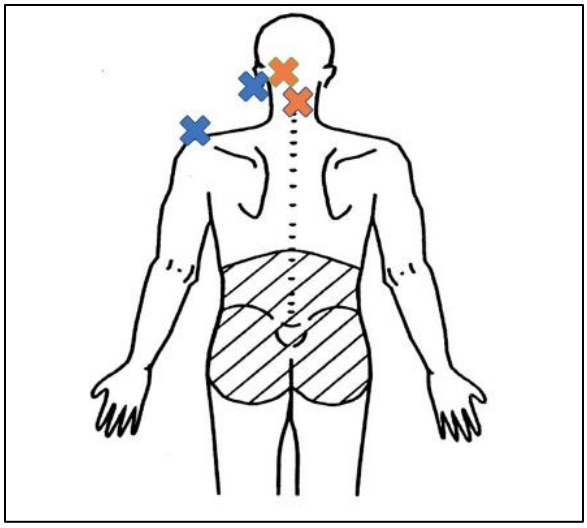


Figure 1: *Schematic showing location of anatomical reference markers used for measurement comparison. The blue set indicates the left acromion process and left mandibular angle. The orange set indicates the C3 spinous process and left occipital bone. In each set, the distance between the two markers was measured.*

III. Methodology

Participants

Participants for this research study were solicited either by email, mail, verbal invitation, or phone conversation. Fliers were posted and community music teachers were contacted to ask their students if they would be interested in participating. In order to join the study, the participant had to be at least 18 years of age, have had training of at least three years of music lessons in either violin and viola, and the ability to read sheet music. Exclusion criteria were professional musicians and any musicians who were currently experiencing intense pain due to their playing or another physical condition that could be exacerbated by participation. The reasoning for excluding professional musicians from the study was due to the research done by Rickert, Barret, and Ackerman (2015) who found that professional musicians tended to have already worked out the best posture for themselves as compared to student musicians who did not yet demonstrate a similar level of postural awareness.

Demographics

Participants were asked in a pre-AT questionnaire if their teacher has ever discussed the topic of injury, posture, and/or relaxation during formal lessons. Participants were also asked to give an overview of how much they played their instrument each week and how much, if any, pain they were currently experiencing. Height and age also were recorded.

Instrumentation

Motion-capture cameras and reflective markers were used to track the movement of participants in a motion capture lab. The University of Alabama in Huntsville (UAH) Autonomous Tracking of Movement (ATOM) Lab provided access to 33 Nexus Vicon T40s motion tracking cameras. The cameras were equipped with an Mx Giganet connectivity node as well as Nexus software, near infrared (NIR) strobes, and visible light filters to allow for operation under variable lighting conditions. These motion-capture cameras record the motion of small, bead-like IR-reflecting markers at 515 fps at a full resolution of 4 megapixels.

Procedures

Participants were asked to wear dark athletic clothing including fitted pants, a fitted, short sleeved t-shirt, and to have long hair tied back. Reflective markers were affixed to anatomical landmarks on the head, face, arm, back, and hip locations of participants with non-toxic craft glue dots and disposable, skin-safe Velcro strips, as seen in **Figure 2**. The first set of markers measured was placed between the C3 spinous process and left occipital bone, and the second set measured was placed between the left mandibular angle and acromion process.

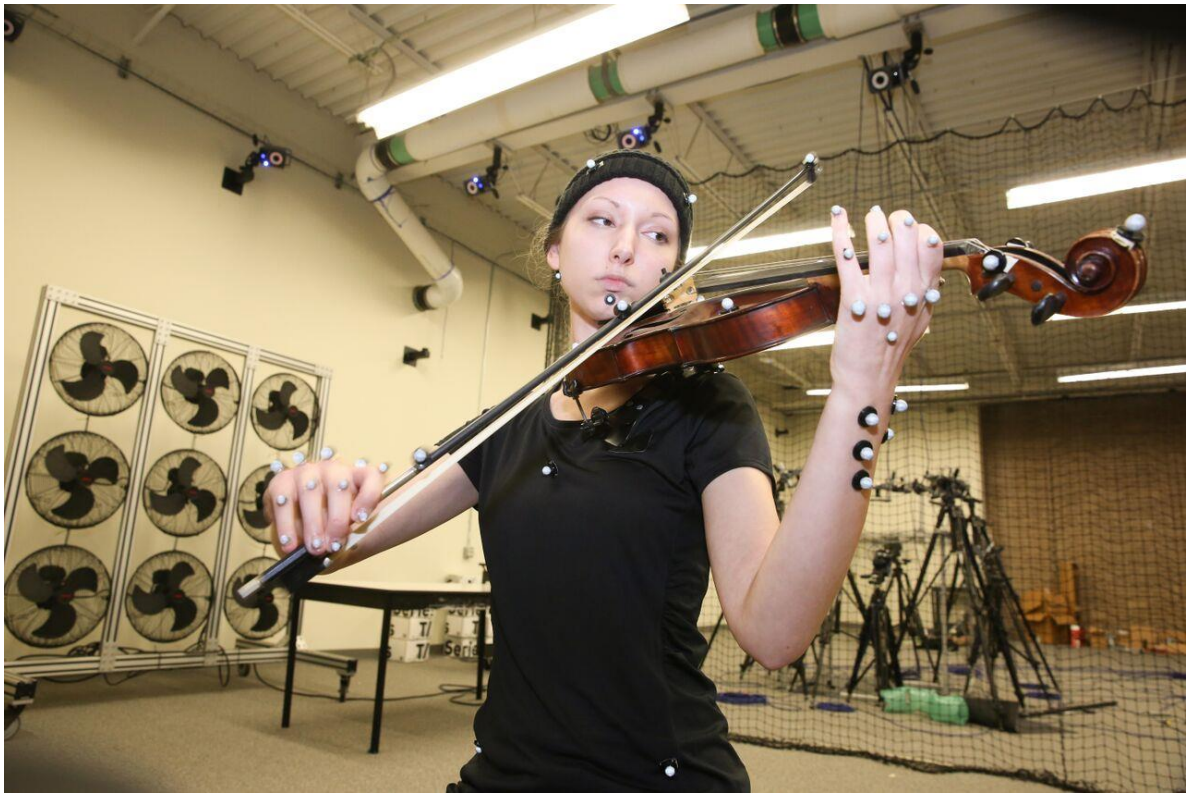


Figure 2: *Photo of the author testing marker placements in the ATOM Lab during study development.*

The participants were encouraged to warm up on their instrument if they so desired before being tracked using the motion capture cameras to observe their movements as they played a simple etude that focused on producing continuous movement of left and right hands. Next, the participants were shown a video of the AT as it relates to a violinist or violist, recorded for the study by a local certified AT practitioner. Finally, the participants were asked to apply what they learned from the AT video and re-play the excerpts while being recorded again by the motion-capture cameras. A written questionnaire was completed before and after AT practice to ask participants to self-assess their own tension, focus, and pain levels on a scale of 1 – 10. A paired sample T-Test was used to analyze mean distances between two sets of reflective markers, and to compare pre- and post-AT self-assessment scores.

IV. Results

For this initial study, four participants were tested: three violinists and one violist. The average number of years playing was 12.0 years, and their mean age was 20.5 ± 1.3. Data are presented in **Table 1**. For the results collected, a Shapiro-Wilk test indicated data are normal. There was a statistically significant difference between the pre- and post-AT measurement of the mean distance between the reflective markers placed at the mandibular angle (M = 149.39 SD = 16.74) and acromion process (M = 154.16, SD = 18.88), (t = 4.36, p = .01). There was no statistically significant difference between the pre- and post-AT measurement of the mean distance between the reflective markers placed at the C3 spinous process (M = 117.96, SD = 17.08) and the occipital bone (M = 126.5, SD = 11.36), (t = 2.02, p = .30). However, the mean distance was larger in three of the four participants.

For the questionnaire, tension, focus, and pain were all ranked on a scale of 1 – 10. Data are presented in **Table 2**. There was no statistical difference in tension, focus, or pain. **Figure 3** presents a computer model of a marker placement test. See also **Figures 4, 5, 6, and 7** for data charts representing the XYZ axis differences in pre- and post-AT tests for both marker sets from a participant.

Table 1: *Comparison of the distance between reflective markers pre- and post-Alexander Technique*

Marker placement	**Pre-AT M ± SD**	**Post- AT M ± SD**	**t**	**p**
Mandibular Angle and Acromion Process	149.39 ± 16.74	154.16 ± 18.88	4.36	.01
C3 Spinous Process and Occipital Bone	117.96 ± 17.08	126.5 ± 11.36	2.02	.30

Note. Distance was measured in mm. A paired samples T-Test was used to analyze data over a 10 - 60 sec time period during the instrumental playing.

Table 2: *Self-Questionnaire results from participants in pre- and post-AT tests*

	Pre-Test Tension	**Post-Test Tension**	**Pre-Test Focus**	**Post-Test Focus**	**Pre-Test Pain**	**Post-Test Pain**
Participant 03	4	4	8	8	3+	3
Participant 04	4	1	6	9	2	2
Participant 05	2	2	7	5	1	1
Participant 06	1	1	6	6	1	1

Note. Tension was measured on a scale of one (lowest) to 10 (highest). Focus was measured on a scale of one (poor) to 10 (excellent). Pain was measured on a scale of one (no pain) to 10 (highest pain).

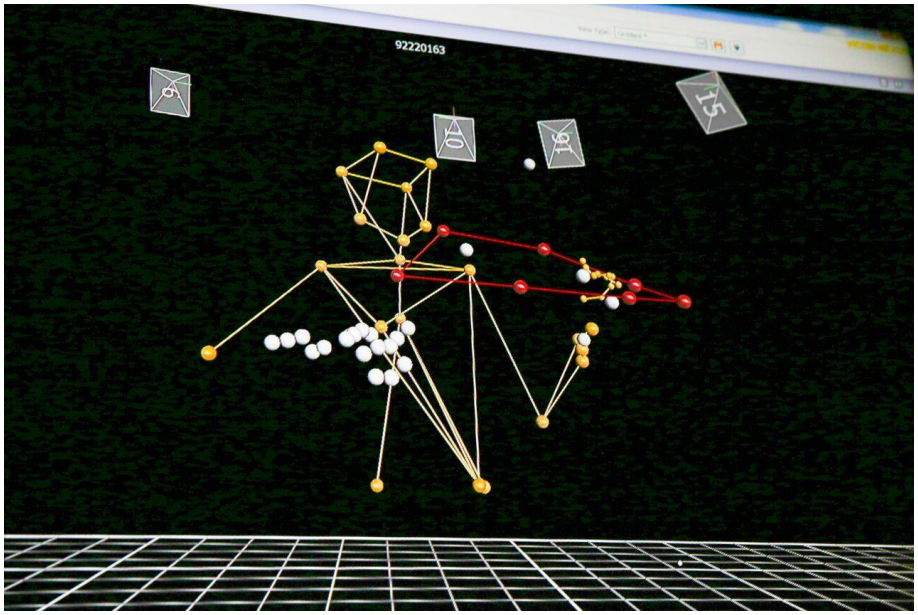


Figure 3: *Computer rendering of the author testing reflective marker placement and camera angles. Each dot represents a reflective marker, with the yellow dots indicating anatomical landmarks and red dots indicating the violin. The numbered boxes in the upper part of the photo indicate placement of some of the motion-capture cameras.*

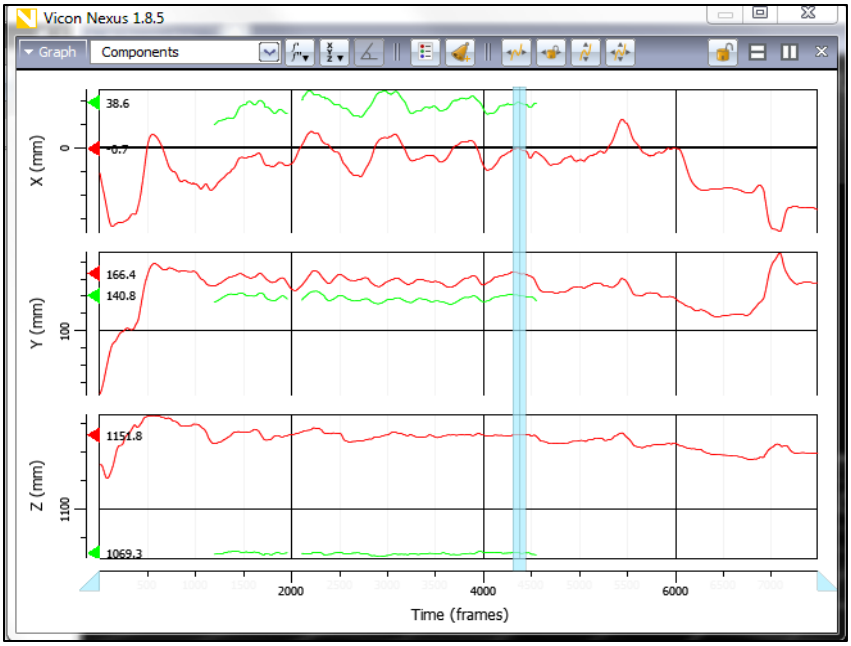


Figure 4: *Sample view of computer software showing XYZ axis of movements between the C3 spinous process and left side of the occipital bone showing approximately thirty seconds of playing time from Participant 1, Trial 1. The green line shows the C3 spinous process and the red line shows the left side of the occipital bone.*

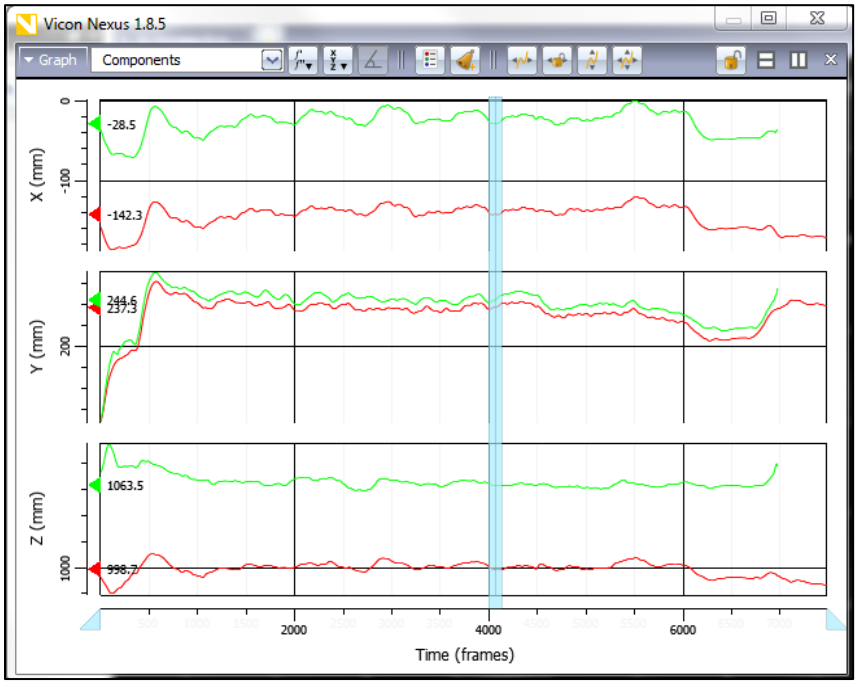


Figure 5: *Sample view of computer software showing XYZ axis of movement between the left mandibular angle and left acromion process showing approximately forty seconds of playing time from Participant 1, Trial 1. The green line shows the left mandibular angle and the red line shows the left acromion process.*

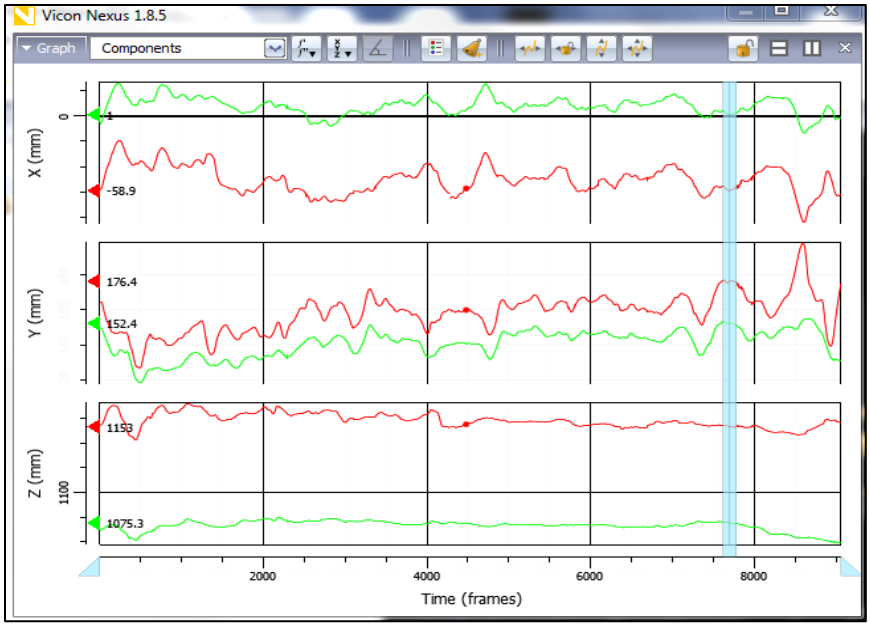


Figure 6: *Sample view of computer software showing XYZ axis of movement between the C3 spinous process and left orbital surface showing approximately forty seconds of playing from Participant 1, Trial 2. The left orbital surface is in red and the C3 spinous process is in green.*

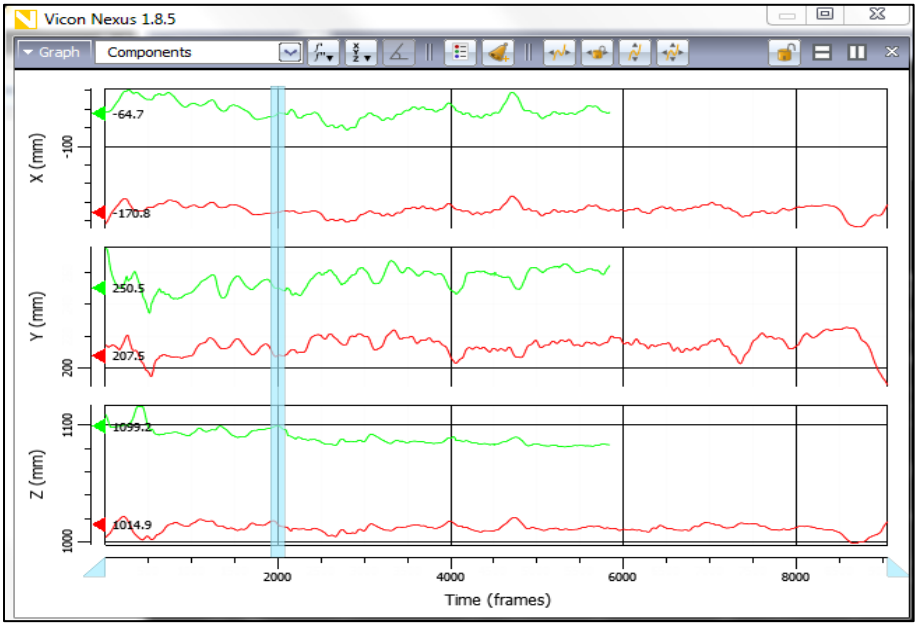


Figure 7: *Sample view of computer software showing XYZ axis of movement between the left mandibular surface and left acromion process showing approximately thirty seconds of playing from Participant 1, Trial 2. The left acromion is in red and the left mandibular angle is in green.*

V. Discussion

Musician injury is an issue that often goes unspoken or ignored by instrumentalists. This can be particularly true for student musicians who do not have the experience or training necessary to fully understand healthy practicing methods. The research demographic of this study focused on student musicians due to the higher likelihood they have of ignoring ongoing pain and tension signals. Professional and career musicians do sustain injuries due to their high volume of playing, but are more likely to seek out treatment when injuries do occur. Conversely, students can become trapped in cycles of physical damage and overuse (Rickert et al., 2015). Finding a reproducible way to reduce tension and pain in student musicians has the potential to help teach the awareness that professional-level musicians have at a much earlier stage for the student musician.

The AT was chosen as the tension-reducing method due to its gentle approach and prevalence as a treatment routine among musicians. Because the AT focuses on elongating the neck and spine by engaging muscles embedded around the backbone, it has potential to move participants out of poor postural habits. Applying AT methods allows the user to align their body into a more natural position and combat the effects of holding a violin or viola—which often require a musician to tilt and compress their head, neck, shoulders, and arms into unnatural positions.

The hypothesis that was developed for this research study theorized that practicing the AT would reduce tension and pain in violinists and violists by bringing them into a more relaxed and ergonomic alignment. Through the AT, it was hypothesized that more distance would be created between the left jaw and shoulder (left mandibular angle and left acromion process) markers if tension was reduced, which would allow the muscles in that area to relax and "let down." The hypothesis for the back-left head and spine (left occipital bone and C3 spinous process) marker set was that there would be less space between these markers if the AT reduced tension coming from the downward pressure of the head, allowing the head to rotate upwards slightly from the chin.

Results indicated that the measurements between the left mandibular angle and left acromion process were statistically different, indicating an increase in length between the two markers. The comparison criteria hypothesized that there would be an increase in length between these points if the AT either reduced the amount of compressed, downward pressure the musician was placing onto their instrument from the chin, or alternatively if the amount of upward pressure the participant was producing from the shoulder to lift the instrument was decreased.

Results for the C3 spinous process and occipital bone were not statistically different. However, there was a change as the mean distance between the two markers was longer. The comparison criteria hypothesized that the AT would shorten the distance between those two points, however the opposite occurred in three out of four tests.

Results of the study proved the hypothesis to be true with the marker set on the left mandibular angle and left acromion process: there was a statistically significant increase in the distance between the two markers after the participants watched an instructional video on the AT. This would indicate that the left shoulder most likely dropped due to either increased awareness or a state of greater relaxation.

The reason for measuring the distance between the jaw and the shoulder was to determine if some of the compression in the head and neck area of violinists/violists could be reduced. The constant turning, dropping, and holding of the jaw to the instrument has the potential to cause injury, especially if the musician is also lifting their left shoulder to create more stability. The AT, particularly if combined with a customized chin rest or shoulder rest fitted to a violinist's/violist's neck length could reduce tension that is commonly experienced, but not often noticed.

The hypothesis was not proven in the marker set placed on the occipital bone and C3 spinous process. In three out of four tests, there was a greater amount of space between the markers rather than a lesser amount of space. Measuring the distance between the back-left head and upper spine was chosen because a violinist's/violist's head can tend to be pressed down onto the instrument, particularly if the chin or shoulder rest are too short for the musician's neck. The thought process behind this hypothesis was that relieving tension in this area would allow the head to not be as forcefully pressed into the instrument, raising it and shortening the distance between the markers. However, this did not consider the fact that the chin rest height was not changing during the testing so it was relatively impossible to shorten the distance between the marker set (as there was no way that the participant's head could come up without using the shoulder to raise the instrument in compensation). Therefore, the results seen may be due to the focus that the AT has on lengthening the spine, which would create greater space between those two areas. This would send non-corroborative results over the original hypothesis that

it would prevent the head from dropping unnecessarily.

The self-questionnaire was given to allow the musicians to assess themselves on what the process with the AT felt like to them. The scaled questionnaire ranking tension, focus, and pain from 1 – 10 allowed a ballpark estimate of how they perceived each of these elements and how the AT affected them. Overall results show a variety of response. None of the participants experienced an increase or decrease in pain (if any was present). Nearly all the participants indicated better focus after watching the AT lesson as opposed to before. Three participants rated their tension levels as staying the same, and one participant rated less tension post-AT lesson.

Three of the participants reported that they had either experienced pain/discomfort in the past or were currently experiencing pain in the present, although not to an extent they had stopped playing. One participant was actively seeking physical therapy for their pain. It must be pointed out that it is important to encourage students to be verbal about pain or discomfort they may be experiencing while playing. In a research survey of college cellists, authors Rickert et al. (2015) reported that the student cellists they interviewed showed poor awareness of how to respond to the pain and tension they were actively experiencing, instead shrugging it off and continuing in practice patterns that would ultimately be damaging to their health. In contrast, the professional musicians that the researchers interviewed demonstrated a much higher awareness of how to pace themselves and be more conscious of when their bodies were showing signs of overuse (Rickert et al., 2015).

The participants who reported experiencing pain in this study did show active awareness of it, but did not always know why it was happening or how to combat it. This is relevant to this study because so many of the injuries—especially overuse injuries—that student musicians develop could potentially be prevented or offset with better awareness and self-disclosure of pain to seek treatment options. Therefore, there are two fronts that musician injury must be fought on: creating awareness and then finding a diagnosis and viable treatment plan.

The participants were provided the opportunity to write down their overall thoughts on the experience after the testing was complete. A common theme from this feedback was that the participants could see potential in the method for reducing tension and noticed a difference either in the way they were thinking about their playing or the way it felt. However, three of four of the participants indicated that the short instructional video was not enough to produce a significant or lasting change.

Conclusions

The overall conclusion of this study is that the AT does have the potential to influence the amount of tension that violinists and violists experience and enhance relaxation and awareness levels. There was no significant indication that the AT could change pain levels. Some limitations that the study faced were a lack of participants due to the specific demographic tested (non-professional musicians over the age of 18). Another constraint was that the study was unable to offer more than a short instructional video on the AT.

Considerations for future research in this area would be to offer a more in-depth AT experience for participants as preliminary data indicates that a one-on-one live session with an AT practitioner and participant would give clearer testing results. An improved experiment design could provide the additional data needed to confirm and expand on these initial results For example, an eight-week randomized control trial could be performed where half the participants were trained in AT methods while the other half practiced as normal. Additionally, further recommendations for future research would be to expand measurements to include biological indices (heart rate, blood pressure, results of additional test sessions) with a larger sample of participants.

VI. Acknowledgments

The author would like to gratefully acknowledge the assistance of Andrew Creech for being a master wand-waver and camera operator, Madhu Sridhar for giving invaluable assistance and instructions for the Vicon camera system, Dr. Barbara Hudson for providing the AT instructional video, Dr. Ryan Conners for assisting with anatomical placement elements, Alex and Darnisha for assisting in the lab, and Zella Brown and Shatura Hall for their collaboration and assistance in the research process. Also, many thanks to Dr. Shannon Mathis for her assistance with data calculations and interpretation, and Dr. Brian Landrum for facilitating and mentoring the study.

References

Ackerman B., & Chan, C. (2014). Evidence-informed Physical Therapy Management of Performance-related Musculoskeletal Disorders in Musicians. *Cognitive Science*. 5(706)

Foxman I. & Burgel B.J., (2006). Musician Health and Safety: Preventing Playing-related Musculoskeletal Disorders. *AAOHN J.* 54(7), 309–16

Fry, H. J. (1988). The Treatment of Overuse Syndrome in Musicians. Results in 175 Patients. *J R Social Medicine.* 81(10), 572 – 575

Hagberg M, Thiringer G, Brandström L. (2005). Incidence of Tinnitus, Impaired Hearing and Musculoskeletal Disorders among Students Enrolled in Academic Music Education: A Retrospective Cohort Study. *International Archives of Occupational and Environmental Health.* 78(5), 75–83. PUBmed.

Lukomski, L. (2004). Common Injuries of Musicians. Honors Thesis. Paper 1635.

Mayers, H., & Babits, L. (1987). A Balanced Approach: The Alexander Technique. *Music Educators Journal.* 74(3), 51 - 54. JSTOR. Web.

Moraes, G.F.S. & Atunes, A.P. (2012) Musculoskeletal Disorders in Professional Violinists and Violists. Systematic review. *Acta Ortopedica Brasil.* 20(1), 43 - 47.

Nyman T., Wiktorin C., Mulder M., & Johansson Y.L., (2007) Work Postures and Neck-shoulder Pain among Orchestra Musicians. *American Journal of Industrial Medicine*. 50(5), 370–6

Palmer, C., Koopmans, E., Loehr J.D., & Carter, C. (2009). Movement-Related Feedback and Temporal Accuracy in Clarinet Performance. *Music Perception: An Interdisciplinary Journal*. 26(1), 439 – 449. JSTOR. Web.

Peterson, P. (2008). On the Voice: Alexander or Feldenkrais: Which Method Is Best? *The Choral Journal*, 48(11), 67-72.

Rickert, D. L. L., Barret, M. S., & Ackermann, B. J. (2015) Are Music Students Fit to Play? A Case Study of Health Awareness and Injury Attitudes amongst Tertiary Student Cellists. *International Society for Music Education*. 33(4), 426 - 441.

Shan, G. Visentin, P. and Harnett, T. (2010). A Novel Use of 3D Motion Capture: Creating Conceptual Links between Technology and Representation of Human Gesture in the Visual Arts. *Leonardo.* 43(1), 34 - 42, 17.

Toiviainen, P., Luck G., & Thompson, R. (2010). Embodied Meter: Hierarchical Eigenmodes in Music-Induced Movement. *Music Perception: An Interdisciplinary Journal.* 28(1), 59 – 70.

Gentrification and Police Brutality

LaDeana Phillips
Department of Political Science

Abstract – This research is an attempt to discover how gentrification and police brutality are related. Drawing on scholarship from social scientists who have researched the implications of gentrification at length and from those who have examined the underlying cause of why the use of excessive force by a security apparatus may occur, I extrapolate a relationship between the two events and conclude that they are in fact related. For the purpose of this analysis, gentrification is defined as spatial segregation through the reclamation of lower-class, urban space by middle and upper-class citizens. This reclamation of urban spaces displaces those of lower socioeconomic classes (typically composed of people of color), colonizes the space for the middle and upper-classes, and relies heavily on legitimized auspices of power such as a police force. Police brutality is defined as the use of excessive force, at times resulting in death, by a publically-funded security force. The research of this paper will suggest that when people of color are conspicuously displaced they become perceived as intruders within their own communities and heightened police surveillance escalates situations of tension into a threat.

First, I will examine the process of gentrification and spatial commodification. By asserting that gentrification is an economic policy of revitalization in a globalizing economy, what follows is a social cleansing that eliminates the obstacles to commodified space. Next, I will move on from gentrification and spatial commodification to the consequences of a "zero-tolerance" policing strategy as it is examined in the context of whether gentrification has increased crime to the point of its necessity. The concluding analysis shows how recently gentrified areas and the use of increased police surveillance result in use of excessive force by a policing mechanism.

I. Gentrification: Class Warfare in Urban Centers

Consider that the composition of a neighborhood, be it urban or rural, is the result of an economic reality. Those who can afford to move away from their workplaces in an industrialized society do so, while the inverse is also true. Now, let us assume that these same neighborhoods have life cycles reliant upon the economic status of a relatively homogenous group as it collectively grows or shrinks. As a group becomes more affluent, certain amenities become available and when a group loses socio-economic status fewer amenities are available. These life cycles are subject to and in some cases are the push and pull factors of urban settlement. Typically, the working classes and minorities inhabit the urban center (Engels 1935).

In an increasingly globalized economy the composition of an urban center is changing. Gone are the days of industrialized workforce cohabitation in "the breeding places of disease, the infamous holes and cellars in which the capitalist mode of production confines our workers night after night," as Friedrich Engels once famously penned in his discussion on the shifting housing question (Engels 1935). Now, the revitalization of city centers is more likely a draw toward amenities than it is toward the availability of work. Spatially concentrated changes, like gentrification, rely heavily on economic, social, and population changes. Gentrification is a reflection of the changing economy of an urban center as it alters the demographic of neighborhoods. This move back to the city by the more affluent class is, in places like New York, creating an increased residential polarization of income levels, educational attainment, and ethnicities. The evolution of an urban economy has moved from manufacturing to services, created a redundancy in workforce (as there is now less demand for labor) and thus created a decline in economic viability (Marcuse 1985). The urban center is no longer the seat of manufacturing instead; it is increasingly becoming a commercial playground for services (Marcuse 1985).

The globalization of urban centers has created a business of culture. This business of culture commodifies the urban landscape to reflect a city's global reach by bringing in a myriad of cultural affectations (e.g., cuisine, religious iconography) as niche markets and entertainment centers. These cultural bazaars blend into the landscape without segregation of race (Pérez 2002). The influx of the middle and upper classes toward these amenities has, however, created an environment of residential

segregation by social stratification that forces out the urban poor through economic means or by force.

An economic policy of revitalization becomes a social project of globalized economies. The urban poor must be displaced as they represent obstacles to new development. Gentrification occurs when these lower-class neighborhoods are "reclaimed" by the more affluent classes for access to and the development of amenities not found in the suburbs. Neil Smith likens this reclamation to that of Westward expansion after the Louisiana Purchase (Smith 1996). By considering the urban landscape as a New Frontier, as Smith suggests, reclaiming it from the wilds of its indigenous population—the working class—explains how easily a security apparatus such as the police force can be an instrumental tool in ushering out undesirables. The myth of the Urban Frontier, Smith argues, "rationalizes the violence of gentrification and displacement" in an effort to cleanse the space for economic development (Smith 1996, pg. 22). It is necessary, for reclamation, that the area be scrubbed of any reminder of the working-class citizen as a means by which to take the area back to a *tabula rasa* so that its history can be rewritten by its conquerors.

Reclamation is a fascinating phenomenon in that the poorer classes are simultaneously visible (e.g., eyesores discouraging development, dangerous) and invisible because after a while they have been pushed out to the margins of communities. This commodification is a boon for economic growth and is more often than not supported by local government policies. As the urban landscape evolves into a commodified space of cultural business the visibility of its "indigenous" residents decreases.

II. The Myth of "Other" and Social Cleansing

The violent young man of color is seen as an intruder in middle-upper-class neighborhoods and represents an "otherness" that no longer adheres to the composition of a community. This is a powerfully evocative narrative; it breeds, grows, and festers in the subconscious until any hooded figure at twilight is certainly a threat. It is perpetuated as a perceived threat, in need of surveillance, for no other reason than no longer adhering to the norms of their neighborhoods (Pérez 2002). The myth of "other" (those who differ from the norm in a neighborhood) is a relatively unfounded threat; there is no threat in the transgression of deviating from the community norm. However, this perceived threat opens the door to increased police presence in gentrified neighborhoods. Police forces are ushered in by community activists and watch-dogs protecting their economic interests.

The myth of "other" is perpetuated through the media's coverage of "the crime problem" in gentrifying neighborhoods (Leverentz 2012). It is also perpetuated by business owners and neighborhood imagination. The narrative of transgression synonymous with lower-class citizens, often young men of color, stratifies neighborhoods into factions of those who belong (mid-upper-class citizenry) and those who do not (lower-class) (Fayyad 2017). When the media runs with stories vilifying lower-class communities as crime ridden and dangerous, then the discourse of the conquering pioneer is to civilize the area. The result is local businesses and residents discouraging patronage from and encouraging increased surveillance of those who no longer belong in the community. The fear of crime legitimizes the auspices of policing in neighborhoods (Conquergood 1992).

Is increased surveillance necessary? Does gentrification drive up crime rates in a retaliatory fashion? Drawing on the conclusions of Scott C. McDonald's longitudinal study of fourteen "gentrified" neighborhoods we see that it is a much more complex issue (McDonald 1986). Oftentimes, neighborhoods (previously deteriorated in a spatially concentrated manner) ripe for gentrification are already situated in higher crime areas compared with a city average (Marcuse 1985). McDonald suggests that the "risk oblivious" who move into these high-risk neighborhoods may grow more risk averse as they age and their investments yield matured returns. In McDonald's fourteen-year study from 1970-1984, inconclusive results suggest (rather than prove) crime may be reduced with gentrification, but there is no way to extrapolate whether or not this is a symptom or a cause. Crime rates have not increased in such a way as to merit increased surveillance. It must, therefore, be the myth of the other which draws the police.

Mayor Rudolph Giuliani's doctrine of "zero-tolerance"—handed down in Police Strategy Number 5—was no more than a social cleansing strategy spearheaded by Business Improvement Districts (BIDs), real estate, and private homeowners' coalitions in protection of shopping and residential districts (Jefferson 2017). Police Strategy Number 5 was intended to restore the city of New York to its "rightful citizens" (Smith 2001). The affluent newcomers had more political influence than their predecessors (McDonald 1986). This influence and articulation of political clout by private actors spurred the New York Police Department to purge the city of

"scum" (as Mayor Giuliani referred to the unlicensed street vendors, prostitutes, drug dealers, and other undesirables in his policy). Police Strategy Number 5 was overwritten by class and race norms that very clearly express rhetoric of affluent privilege complementary to urban regeneration, or rather gentrification.

The prevalence of heightened surveillance can be directly linked to private sector actors who are determined to revitalize the city's real estate and its economic structures that amplify prejudices (Jefferson 2015). The New York Police Department of the 1990s followed the previously initiated Operation Pressure Point (OPP) tactics of 1983 Lower East Side. The OPP was designed to remove drug markets from desirable real estate (thus, not fixing the drug trade problem, simply relocating it). After its implementation, the Lower East Side became a more affluent neighborhood and was viewed as a success by community activists and the New York Police Department (Jefferson 2015). The affluent community had conquered the wilds of the Lower East Side and settled it for their benefit.

The police department in this regard is used as a tool for "improving" the "quality of life." It is crucial to cleansing the urban landscape while businesses and policy-makers try to attract "cultural infrastructure" (Jefferson 2015). By conducting, as was the case with New York, bi-weekly police sweeps predicated on racial profiling, aggressive handling of low-level disorders led to an increase in police brutality. In 1999 the New York City Police Union announced that "zero-tolerance" tactics are the "blueprint for a police state and tyranny" (Jefferson 2015). The tactics encourage race and class profiling even though there had been no evidence of an increase in crime rates. In fact, Neil Smith in 2001 showed that there was a twenty percent decrease in crime rates between 1990 and when the police strategy was implemented in 1994 (Smith 2001, pg. 72). These policies also minimize concerns about evidence, a practice that has become part and parcel of the 42nd Precinct in New York City to this day.

III. In the Cases of New York and San Francisco

The effect of policies like Police Strategy Number 5 have far reaching implications. Shaun King, prominent civil rights activist, has conducted a methodical study of the 42nd Precinct in the Bronx neighborhood of New York City. The 2017 study discusses a rampant abuse of authority by police officers predicated upon arrest quotas and the Stop and Frisk policy (which has now been officially banned) in the gentrified area of the Bronx (King 2017).

King notes that gentrification has created an invisibility of police brutality for the new residents. However, on the fringes of the neighborhood, where privileged classes rarely visit, police officers are free—if not expected—to terrorize the marginalized classes. According to King, "stop and frisk has been banned, but police in the 42nd precinct are actually doing something far worse. They are setting quotas and goals for the number of people each officer must arrest. If you don't meet or exceed the quotas, you feel the wrath of your supervisors" (King 2017, pg. 1). In his research, King found that five million incidents of Stop and Frisk have occurred in New York City since 2002 with ninety percent of those stops resulting in proof of innocence (King 2017, pg. 2).

However, King notes that as detrimental as the Stop and Frisk policy was, the informal policy of arrest quotas to clean up the streets was far worse. In November 2016, the city of New York agreed to pay $75 million in settlements for police corruption cases. In the lawsuit *Stinson v. NYC*, the city admitted to dismissing over 900,000 false arrests and summonses due to a lack of evidence. The arrest quota system is highly contestable and is currently under review by policymakers and the plaintiffs (twelve New York City police officers) note that the system is predisposed to racial profiling and predatory practices toward people of color and those of lower economic status (King 2017, pg. 2). New York City may have been the genesis of "zero-tolerance" policing policies but these policies do not exist in a vacuum.

On March 21, 2014, Alejandro Nieto was murdered by the police in a gentrified neighborhood of San Francisco (Bernal Heights). Nieto was an upstanding citizen of color with a security guard position at a local nightclub, a job that required him to carry a Taser. While Alejandro sat on a park bench having dinner in Bernal Heights Park, someone called 911. A resident of the neighborhood identified Nieto as a suspicious character (Solnit 2016). Four police officers responded to the call and with little provocation (there is argument whether or not Nieto's Taser was particularly menacing or even powered on) two of the officers unloaded more than two gun clips into Nieto. Alejandro Nieto died from the fourteen bullet wounds he sustained. It is also to be noted that police opened fire, unprovoked, in a public park with no regard for potential loss of life from innocent bystanders. The escalation of a non-conflict situation resulted in the death of an innocent citizen.

These examples of violence and corruption do not prove that policies like OPP, Police Strategy No. 5, and Stop and Frisk result in police brutality at the hands of gentrification. However, for the purpose of this research, they do suggest that these policies—based on economic development goals—are a form of social cleansing for economic purposes. That is to say, the need for "zero-tolerance" and reclamation of city streets from the margins of society, are a far more likely causes for increased police surveillance and therefore increasingly violent encounters between the police and the displaced, than actual increases in crime rates.

IV. Conclusion

The class warfare inherent to gentrification remains largely invisible to the affluent classes. Gentrification is class warfare and the police force is its cavalry. It is entirely possible that gentrification has its roots in residential segregation and thereby racial segregation. Here, it appears that police brutality is a feature and necessity of gentrification and serves to socially cleanse areas for neighborhood economic potential. Neighborhoods (developed or developing) and the stratification of economic attainment must be decriminalized in the eyes of the public, thereby stemming the tide of rising police presence in gentrifying areas.

The litmus test of police brutality and gentrification cannot be reduced to such a simple explanation as given herein; however, this argument raises the question of economic development policies that exploit publicly funded security forces and their adherence to the will of the affluent in favor of working-class citizens. If, as posited, the police serve as a social cleansing mechanism then perhaps policies of development must be rendered to their core intention (economic growth) and local governments should regulate housing markets in a more egalitarian fashion.[1]

[1] The development theories of urban centers discussed herein are from the past thirty years. However, these theories are still viable today as the evolution of time has seen the advancement of these ideas. It is intended to build from historical context the notion that this is not a new phenomenon.

References

Conquergood, Dwight. 1992. Life in Big Red. In: *Structuring Diversity*, Louise Lamphere (ed.) Chicago: University of Chicago Press, pp. 95-144.

Engels, Friedrich, 1820-1895. The Housing Question. New York: International Publishers, 1935.

Fayyad, Abdallah. 2017. The Criminalization of Gentrifying Neighborhoods. The Atlantic. - Online.

Jefferson B.J. 2017. US Regional: The US Policing Crisis and Urban Redevelopment: Tracing the Links in New York. In: Gamerith W., Gerhard U. (eds) *Kulturgeographie der USA*. Springer Spektrum, Berlin, Heidelberg

Jefferson, B. J. 2015. Enforceable Environments: Spaces of Policing, Sustainability, and Environmental Rhetoric. In: Wilson, D. (2015): *The Politics of the Urban Sustainability Concept*. Champaign, IL: Common Ground Publishing.

King, Shuan. 2017. Soul Snatchers: How the NYPD's 42nd Precinct, the Bronx DA's Office, and the City of New York Conspired to Destroy Black and Brown Lives (Part 1). Medium. Online.

Leverentz, Andrea. 2012. Narratives of Crime and Criminals: How Places Socially Construct the Crime Problem. *Sociological Forum*, Vol. 27, No. 2 (June 2012), pp. 348-371

Marcuse, Peter. 1985. Gentrification, Abandonment, and Displacement: Connections, Causes, and Policy Responses in New York City, 28 Wash. U. J. Urb. & Contemp. L. 195

McDonald, Scott. 1986. Does Gentrification Affect Crime Rates? *Crime and Justice*, Vol. 8, Communities and Crime. The University of Chicago Press. pp. 163-201

Pérez, Gina M. 2002. The Other "Real World": Gentrification and the Social Construction of Place in Chicago. *Urban Anthropology and Studies of Cultural Systems and World Economic Development*, Vol. 31, No. 1. pp. 37-68

Smith, Neil. 1996. *The New Urban Frontier*. Routledge.

Smith, Neil. 2001. Global Social Cleansing: Postliberal Revanchism and the Export of Zero Tolerance. *Social Justice*, Vol. 28, No. 3 (85) Law, Order, and Neoliberalism pp. 68-74

Solnit, Rebecca. 2016. Death by Gentrification. The Guardian. Online.

Economic Indices: An Analysis of the Space Industry

Emily Sexton
Department of Economics

Abstract **–** The goal of this report is to analyze available information on economic conditions in the space exploration industry and obtain the information that would be necessary to create a measurement of growth relative to other industries. To accomplish this effectively, a thorough understanding of existing indices would be essential. Indices measure economic change, using calculations which aggregate a vast amount of information into one quantity. Many industries have their own indices which provide information about changes in business conditions. The indices chosen to study for this report are the Institute of Supply Management's Manufacturing Index and the Federal Reserve's Industrial Production Index. The Kensho New Economies Space Index (KMARS), a newly-formed index that tracks stock prices of companies involved in space commerce, is also examined to shed light on the industry. Four firms in the space industry are examined – Aerojet Rocketdyne, Boeing, Lockheed Martin, and Northrop Grumman – to determine the types of economic data available at a firm level.

I. Introduction

An index number aggregates a vast amount of information into a single quantity. These numbers are useful for analyzing changes in data collected on one or more variables over time (called a time series analysis), especially in macroeconomics (Woolridge, 2013). A basic example of an index is the consumer price index (CPI). The CPI is a measure of the level of prices. It is measured by showing the price of a bundle of goods relative to the same bundle of goods in a base year (Mankiw, 2010). To construct an index, a base period and base value need to be established. The base period and value are what each subsequent period and value are compared to in a time series analysis. Time series analyses are used to determine the effect an independent variable x has on a dependent variable y. In a time series, the value of the dependent variable in one period is correlated with its value in the next period. This is known as serial correlation or autocorrelation (Stock & Watson, 2014).

Three indices are examined in this report: the ISM Manufacturing Index, the Federal Reserve Industrial Production Index, and the Kensho New Economies Space Index. Research was conducted on these three indices and their relative industries to determine what the indices reveal about their industries, the methodology by which they are constructed, and what can be learned from them. The Manufacturing Index and the Industrial Production Index provide information on macroeconomic data such as company revenues and employment, while the Kensho Space Index is a stock market index. The long-term goal of this research project is to construct a space index that answers macroeconomic questions about the space industry which the Kensho space index fails to answer, to determine that the manufacturing index and the industrial production index sufficiently answer these questions about their respective industries, and to also determine the relevant information that is needed to answer these questions for the space industry.

II. The ISM Manufacturing Index

Manufacturing is the large-scale production of goods, using labor and machinery, to be sold to customers for use. It can involve the mechanical, physical, or chemical transformation of materials into new products intended for consumption or for use as capital. There are many subsectors of the manufacturing sector, including, but not limited to: food manufacturing, textile products, apparel manufacturing, paper manufacturing, wood product manufacturing, chemical manufacturing, computer and electronic product manufacturing, transportation equipment manufacturing, furniture manufacturing, and miscellaneous manufacturing. Establishments in the manufacturing industry include plants, factories, and mills, but products made by hand or in the home may also be included in this industry (U.S. Bureau of Labor Statistics, 2017).

The Institute for Supply Management (ISM) has constructed a manufacturing index, which observes employment, production, inventories, new orders, and supplier deliveries of over 300 manufacturing firms. This index reflects economic conditions in the U.S., and it serves as a signal to investors about changes in the industry. The index provides adequate information about business conditions in the manufacturing industry to supply

management professionals, economists, analysts, and government and business leaders. The ISM surveys production and supply management firms nationwide and uses the data collected to construct its manufacturing index. Executives of the firms respond anonymously to a monthly questionnaire about changes in production, new orders, new export orders, imports, employment, inventories, prices, lead times, and the timelines of supplier deliveries, comparing the current month to the previous month. The survey also asks for data on commodities and remarks on current business conditions (The Institute for Supply Management, n.d.).

The Institute issues a monthly report on economic activity in the manufacturing industry. On November 1, 2017, it reported an overall expansion in the month of October. The report stated that new orders, employment, production, and backlog of orders continued to grow, while supplier deliveries slowed down. The industry saw a contraction of raw materials' inventories, and customers' inventories were too low (Cahill, 2017). A monthly series was constructed, showing trends in the manufacturing index from 1948 to 2017. The grey shaded areas represent periods of recession, and the red dots represent months leading to recessions (see **Fig. 1**).

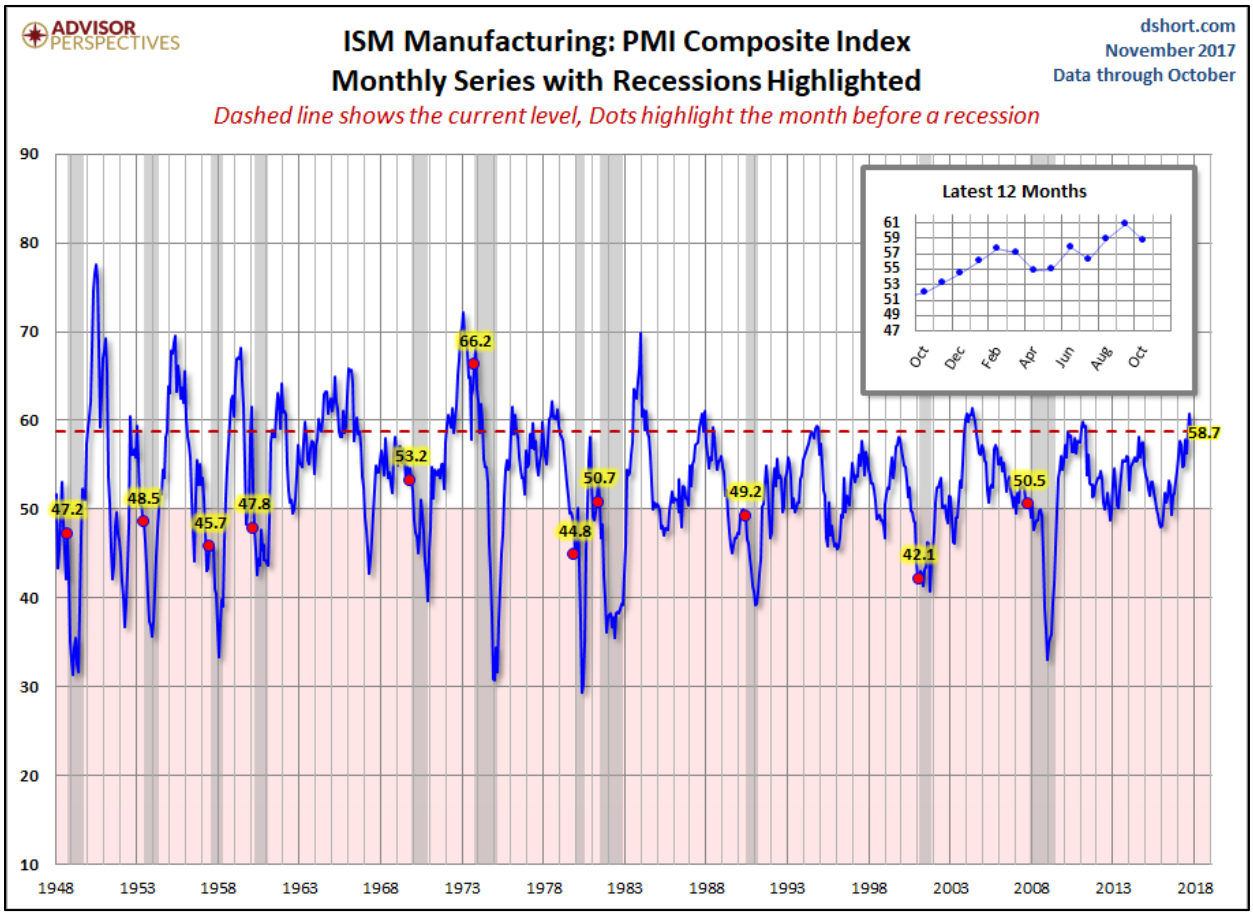


Fig. 1: *Advisor Perspectives. (2017, November). ISM Manufacturing: PMI Composite Index [Chart]. In Advisor Perspectives. Retrieved from www.advisorperspectives.com/images/content_image/data/b2/b27c392429e2f6dfe67c8058ffdf57d1.png*

II. Federal Reserve Industrial Production Index

The Board of Governors of the Federal Reserve releases monthly indices on industrial production and capacity utilization which cover manufacturing, mining, and electric and gas utilities. The industrial production sector, including construction, accounts for much of the national output throughout the business cycle. The industrial production index measures real output as a percentage of real output in a base year, which is currently 2012 (Board of Governors of the Federal Reserve System, 2017, October 12). It is constructed from 299 individual series, classified as market groups and industry groups, based on the 2012 NAICS codes. Market groups are made up of products and materials. Industry groups consist of three-digit NAICS industries and aggregates of those industries. Examples of three-digit NAICS industries are durable and nondurable manufacturing, mining, and utilities. The data for the industrial production index consists of two main types of source data: output measured in physical units (physical product) and inputs to the production process which result in physical output (production-worker hours). To aggregate the IP index, a version of the Fisher-ideal index formula is used. The formula for the monthly growth in industrial production, shown in **Fig. 2**, uses the unit value-added estimate for the current month (p_m) and the estimate for the previous month. The industrial production proportions are estimates of each industry's relative contribution to growth in the following year (Board of Governors of the Federal Reserve System, 2017, March 31). **Fig. 3** shows the trend in the Industrial Production Index from 1919 to 2017, the grey shaded areas indicating periods of recession. The index level falls during recessions and rises following these recessions as business activity picks up.

$$\frac{I^A_m}{I^A_{m-1}} = \sqrt{\frac{\sum I_m p_{m-1}}{\sum I_{m-1} p_{m-1}} \times \frac{\sum I_m p_m}{\sum I_{m-1} p_m}}$$

Fig. 2: *Board of Governors of the Federal Reserve System. (2017, March 31). Formula for Growth in Monthly IP [Image]. Retrieved from https://www.federalreserve.gov/releases/g17/explnote_g17.gif*

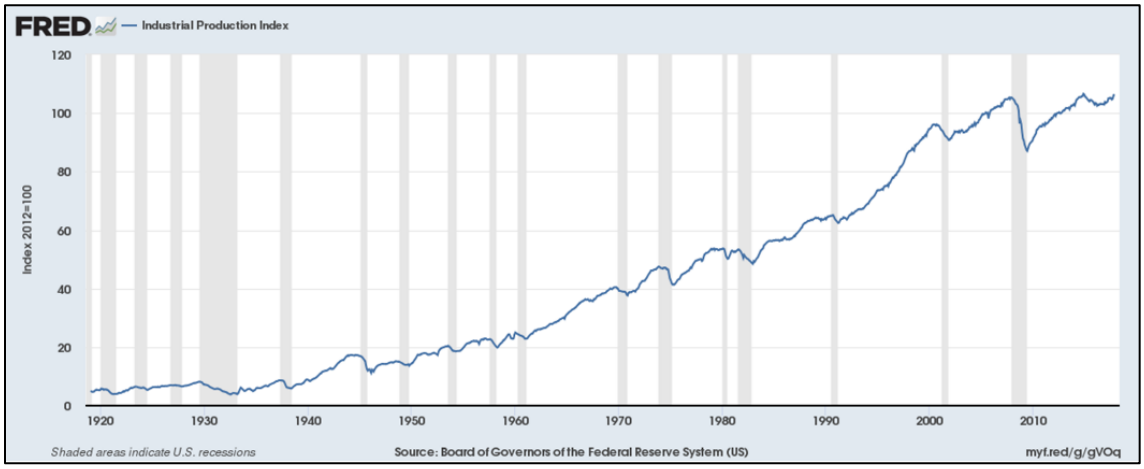


Fig. 3: *Federal Reserve Bank of St. Louis. (2017, December 15). Industrial Production Index [Chart]. Retrieved from https://fred.stlouisfed.org/series/INDPRO*

III. The Space Industry

The space economy is defined as the activities and use of resources involved in exploring, researching, understanding, managing, and utilizing space for the benefit of mankind (Space Safety Magazine, 2014). The global space activity in 2015 totaled $322.94 billion. Of that amount, $126.33 billion (39%) went toward commercial space products and services; $120.09 billion (37%) toward commercial infrastructure and support industries; $44.57 billion (14%) toward US government space budgets; and $31.95 billion (10%) toward non-US government space budgets (see **Fig. 4.**) (Space Foundation, 2016). According to the 2016 Space Report from the Space Foundation, the global space economy grew in 2015. Revenues from commercial sectors comprised more than three-quarters of all global economic space activity. Commercial space products and services, the largest sector, grew by 3.7% to $126.33 billion in 2015. Commercial infrastructure and support industries decreased 5.2% to $120.88 billion. This decline is mostly attributed to global navigation satellite system (GNSS) receivers which were subject to change in currency exchange rates. Global government spending also decreased by 4.8%. US government spending actually increased by 3.2%, while non-US government spending decreased. However, this decline was mostly due to exchange rates. In reality, most governments actually increased spending in the space economy (Space Foundation, 2016). The US employment outlook for the space industry is mixed. In 2014, the U.S. civil and commercial space workforce consisted of 221,585 workers, making it one of the largest in the world. However, it was contracting during this time, while employment in Europe and Japan increased. Future growth is expected for scientific disciplines such as astronomy, but a decline is expected in the demand for aerospace engineers. Demand for non-aerospace disciplines in the space industry, such as programmers, computer scientists, and data analysts is expected to increase in the near future (Space Foundation, 2016). Investment in space infrastructure is continuing to expand around the world. At least 19 countries are hosting or planning to host spaceports for orbital and suborbital launches. In 2015, 86 orbital launches were attempted around the world, which is the highest number in two decades. Two US companies, Blue Origin and SpaceX, successfully landed rockets that returned from space, the most significant development for the space launch industry. The number of large spacecraft being sent into orbit each year has remained relatively constant. Interest in the launch of small satellites has continued to grow. In 2015, nanosatellites made up 48% of the 262 spacecraft launched. However, they made up less than 1% of the total mass sent up into orbit in 2015. Telecommunications satellites made up 41% of the total mass. These satellites generate over $100 billion each year (Space Foundation, 2016).

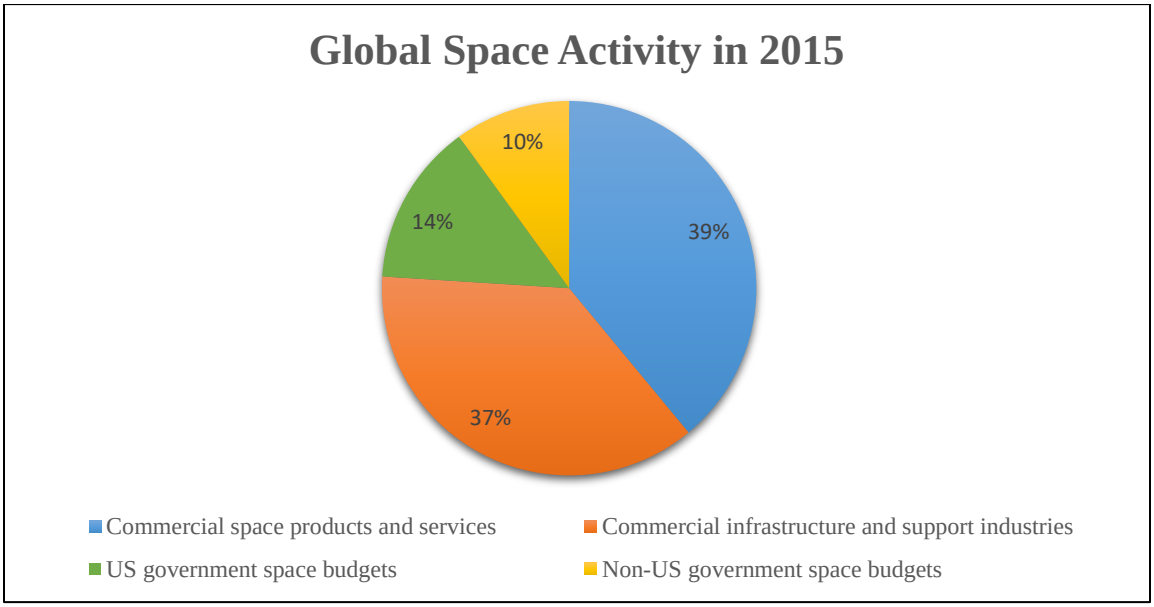


Fig. 4: *Space Foundation. (2016). [Pie chart showing make-up of global space activity in 2015]. The Space Report 2016: The Authoritative Guide to Global Space Activity (Rep.). Retrieved from https://www.spacefoundation.org/sites/default/files/downloads/The_Space_Report_2016_OVERVIEW.pdf*

To obtain more information on the space industry, data was collected on a sample of four companies: Aerojet Rocketdyne, Boeing, Lockheed Martin, and Northrop Grumman. These four companies dominate the space industry in terms of employment and revenues. The following data reflects non-space manufacturing in addition to space manufacturing – the two could not be separated for this report. The reason for this is that some manufactured parts may be used in either rockets or airplanes.

Aerojet Rocketdyne is a major manufacturer in aerospace and defense. The company has seen a steady rise in total revenues, with a 9.9% increase from 2014 to 2016. From 2014 to 2015, there was a 6.6% increase, and from 2015 to 2016, there was a 3.1% increase (see **Fig. 5.**). Data was also retrieved on Aerojet Rocketdyne's employment history. Since 1989, employment has fluctuated but decreased overall. In 2004, employment decreased by 71.5%, though the reason for such a dramatic decrease was not found. From 1989 to 2016, there was an overall 66.7% decrease in the number of employees (see **Fig. 6.**).

Boeing is a large aerospace company which manufactures commercial airplanes and defense, space, and security products and systems. Boeing saw a 5.9% increase in revenues from 2014 to 2015. However, the firm had a decrease in total revenues of 1.6% from 2015 to 2016. The total change in revenues from 2014 to 2016 was 4.2% (see **Fig. 5.**). Boeing employment has decreased over the years. From 2000 to 2016, total employment decreased 24% (see **Fig. 6.**).

Lockheed Martin is a research, development, and manufacturing company in aerospace, defense, and security. From 2014 to 2015, the company saw a small, insignificant increase in revenues. However, from 2015 to 2016, the company had a spike in revenues of 16.6%. Total revenues from 2014 to 2016 increased by 18.3% (see **Fig. 5.**). Total employment in 2016 was 25.5% higher than in 1994. However, employment more than doubled from 1994 to 1995. From 1995 to 2016, employment decreased by 39.4% (see **Fig. 6.**).

Northrop Grumman is another major aerospace and defense company. The company's revenues dropped by 1.9% from 2014 to 2015, but rose by 4.2% from 2015 to 2016. Total revenues increased by 2.2% from 2014 to 2016 (see **Fig. 5.**). While the other three companies saw decreases in employment over the years, Northrop Grumman had an overall increase in employment by 58.5% from 1989 to 2016 (see **Fig. 6.)**. In **Fig. 6**, the trends in employment of the four companies from 2000 to 2016 are shown. A general decrease in employment can be seen following the 2008 recession.

Of the four companies researched, three are members of the Satellite Industry Association (SIA): Boeing, Lockheed Martin, and Northrop Grumman. The SIA releases an annual report on satellite industry data analyses. **Table 1** contains the total revenues of the global satellite industry in the past three years, as well as the total employment in the third quarter of 2016. The revenues of the three companies combined comprise about 6% of the total satellite industry revenues (see **Table 2.)**.

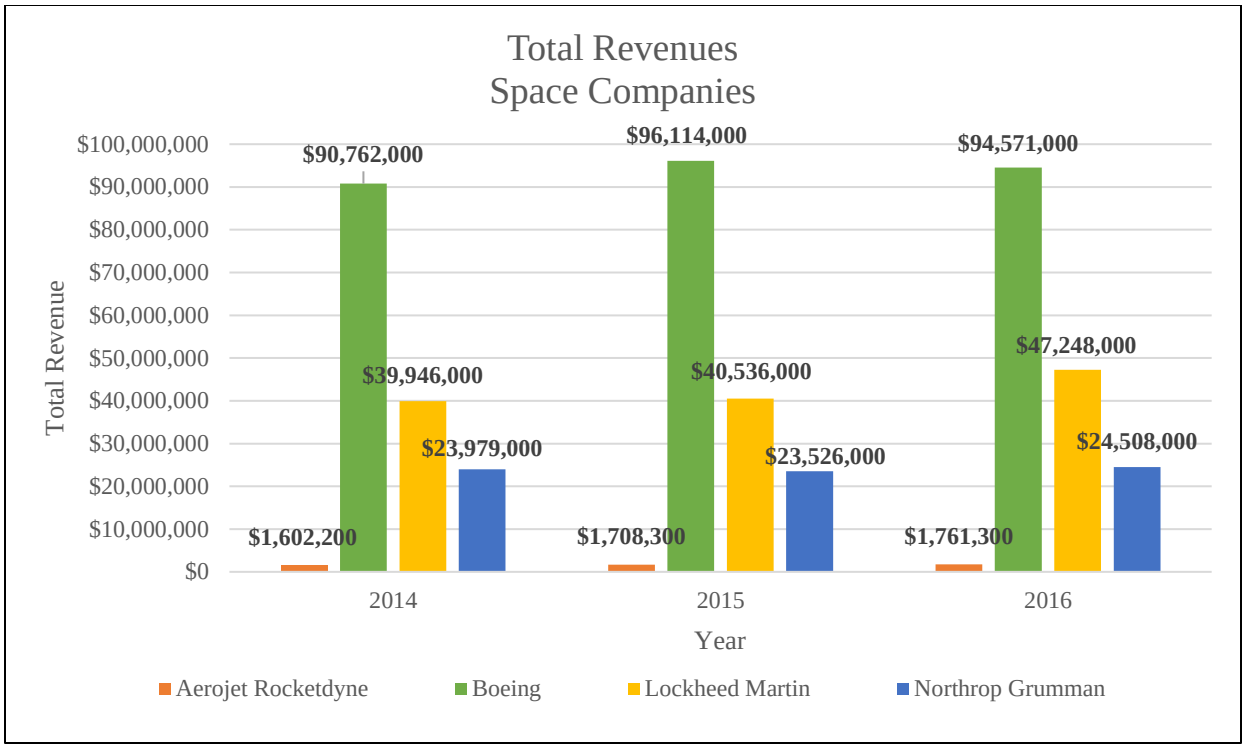


Fig. 5: *Total revenues for space companies in 2014-2016. Data retrieved from Yahoo! Finance.*

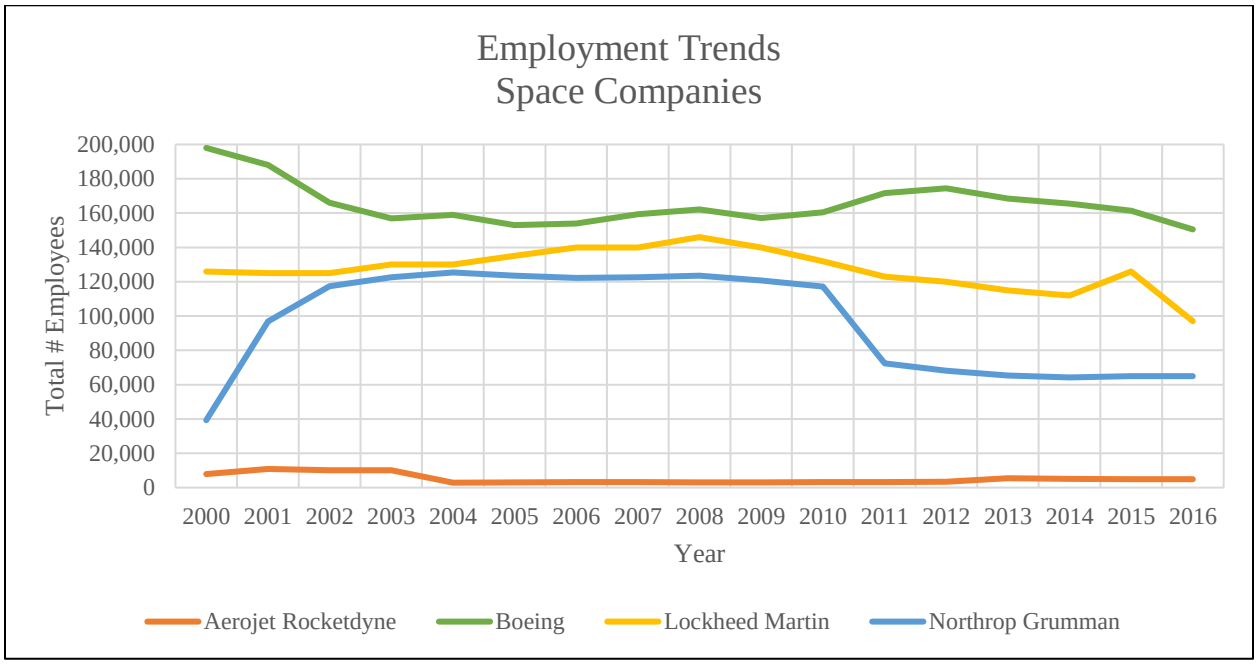


Fig. 6: *Trends in Employment for Space Companies from 2000 to 2016. Data retrieved from Morningstar database.*

INDUSTRY	YEAR	REVENUES (IN BILLIONS)	EMPLOYMENT (3Q 2016)
GLOBAL SATELLITE INDUSTRY	2016	$261	211,185
	2015	$255	
	2014	$247	

Table 1: *Satellite Industry Association. (2017, June). [Table showing total revenues for 2014 – 2016 and total employment in the third quarter of 2016 in the global satellite industry]. State of the Satellite Industry Report 2017 (Rep.). Retrieved from http://www.sia.org/wp-content/uploads/2017/07/SIA-SSIR-2017.pdf*

COMPANY	YEAR	REVENUES	DIFFERENCE	PERCENTAGE
BOEING	2016	$ 94,571,000	$260,905,429,000	3.6234%
	2015	$ 96,114,000	$254,903,886,000	3.7692%
	2014	$ 90,762,000	$246,909,238,000	3.6746%
LOCKHEED MARTIN	2016	$ 47,248,000	$260,952,752,000	1.8103%
	2015	$ 40,536,000	$254,959,464,000	1.5896%
	2014	$ 39,946,000	$246,960,054,000	1.6172%
NORTHROP GRUMMAN	2016	$ 24,508,000	$260,975,492,000	0.9390%
	2015	$ 23,526,000	$254,976,474,000	0.9226%
	2014	$ 23,979,000	$246,976,021,000	0.9708%
ALL 3	**2016**	**$ 166,327,000**	**$260,833,673,000**	**6.3727%**
	2015	**$ 160,176,000**	**$254,839,824,000**	**6.2814%**
	2014	**$ 154,687,000**	**$246,845,313,000**	**6.2626%**

Table 2: *Satellite Industry Association. (2017, June). [Table showing total revenues of three companies as percentage of total revenues of the global satellite industry]. State of the Satellite Industry Report 2017 (Rep.). Retrieved from http://www.sia.org/wp-content/uploads/2017/07/SIA-SSIR-2017.pdf*

IV. Kensho New Economies Space Index

The Kensho Space Index (KMARS) is one of the New Economies indices released by Kensho Technologies, a data analytics and machine intelligence company. It is a stock index that captures 30 companies in the space sector, including the four companies observed for this report. The companies included in the index focus on space exploration and building rockets, launch vehicles, and satellites (CNBC, 2016). Only companies with a market capitalization of at least $300 million and a three-month Average Daily Traded Value (ADTV) of at least $2 million are eligible to be included in the Kensho Space Index (Kensho Technologies, Inc., 2016). The historical performance of KMARS from July 2013 to December 2017 is shown in **Fig. 7**, with the month and year in the x-axis and the index level in the y-axis.

The Index is based on the initial value of 100 at the close of trading on May 15, 2013, the start date. The Index level is calculated with the formula:

$$level_t = \frac{\sum(x_{i,t} \cdot p_{i,t} \cdot f_{i,t})}{D_t}$$

In this formula, $x_{i,t}$ is the number of index shares of the Index Component[1] i on Business Day[2] t; $p_{i,t}$ is the trading price of Index Component i on Business Day t; $f_{i,t}$ is the foreign exchange rate to convert the price of Index Component i on Business Day t into the Index Currency[3]; and D_t is the Divisor on Business Day t. The Divisor on the start date is calculated with the formula:

$$D_t = \frac{\sum(x_{i,t} \cdot p_{i,t} \cdot f_{i,t})}{100}$$

The Divisor at the close of trading on an Adjustment Day t is calculated with the formula:

$$D_t = \frac{\sum(x_{i,t} \cdot p_{i,t} \cdot f_{i,t})}{level_t}$$

The level of the Index calculations, the trade prices, the foreign exchange rates, and the Divisors all must be rounded to six decimal places. The accuracy of the Index calculations is subject to these constraints. Adjustments to the Index are required for systematic changes in prices, requiring that the new Number of Index Shares[4] of the affected Index Component and the Divisor be calculated on an ex-ante[5] basis (Kensho Technologies, Inc., 2017).

The goal of the index is to track the companies that focus on products and services to further enable space travel and exploration (Kensho Technologies, Inc., 2017). While this index sheds some light on the space industry, it is lacking information, such as employment, revenues, production, etc., that is present in the ISM Manufacturing Index and the Federal Reserve Industrial Production Index.

[1] An "Index Component" is a share that is currently included in the Index (Kensho Technologies, Inc., 2017).
[2] A "Business Day" is a day on which the NYSE is open for trading (Kensho Technologies, Inc., 2017).
[3] "Index Currency" is USD (Kensho Technologies, Inc., 2017).
[4] The "Number of Shares" of an Index Component on a given Business Day is the number or fraction of shares included in the Index. It is calculated as the ratio of the Percentage Weight (the ratio of the Trading Price multiplied by the Number of Shares divided by the Index value) of an Index Component multiplied by the Index values, and its Trading Price (Kensho Technologies, Inc., 2017).
[5] "Ex-ante" is a term that refers to future or forecasted events.



Fig. 7: *Solactive. (2017, December 15). Kensho Space Index GTR: Historical Performance [Chart]. Retrieved December 18, 2017 from https://www.solactive.com/wp-content/uploads/solactiveip/en/Factsheet_DE000SLA1G71.pdf*

V. Conclusions and Future Directions

The ISM Manufacturing Index and the Federal Reserve Industrial Production Index provide information about the business activities such as production, employment, inventories, real output, and more in their respective industries. These indices show how business performances have grown or declined over time. This information is vital to investors who need to know the business conditions of the companies and industries in which they are investing. It is also useful for forecasting future trends. The Kensho New Economies space index, while it provides useful information about the space industry to stockholders, does not adequately capture the information on the space industry that the manufacturing and industrial production indices capture on their industries. To combat this lack of information, an index for the space industry that includes variables such as employment, revenues, production, etc. should be created. The data collected on the space industry so far, included in this report, shows that there is a vast amount of information that can be compiled to calculate such an index. Larger databases such as Bloomberg or Morningstar will provide access to relevant information. Time series analyses can be conducted to observe trends in the economic activity of space companies, and the variables affecting changes in the industry can be determined. A base period can be established, and by using an index such as the Fisher-ideal index, future activities can be compared. This will give the user of the index a snapshot of how the industry has performed over time. The Kensho index, while useful, is narrowly focused to assist traders in determining the value of space companies in terms of financial investment. An index like the ISM Manufacturing Index and the Industrial Production Index is much broader, encompassing an entire sector of the economy. An index that tracks space-related economic activities would be a useful index because it will allow us to gauge space activity within the context of the whole economy.

References

Aerojet Rocketdyne Holdings, Inc. (AJRD). Income Statement. *Yahoo! Finance*. Retrieved from https://finance.yahoo.com/quote/AJRD/financials?p=AJRD

Board of Governors of the Federal Reserve System. (2017, October 12). About the G.17. Retrieved from https://www.federalreserve.gov/releases/g17/About.htm

Board of Governors of the Federal Reserve System. (2017, March 31). Industrial Production Explanatory Notes. Retrieved from https://www.federalreserve.gov/releases/g17/IpNotes.htm

The Boeing Company. (BA). Income Statement. *Yahoo! Finance.* Retrieved from https://finance.yahoo.com/quote/BA/financials?p=BA

Cahill, K. (2017, November 1). Manufacturing ISM® Report on Business®. Retrieved November 18, 2017, from http://www.instituteforsupplymanagement.org/ISMReport/MfgROB.cfm?SSO=1

CNBC. (2016, December 02). Kensho Space Index (KMARS). Retrieved December 18, 2017, from https://www.cnbc.com/kensho-space-index/

The Institute for Supply Management. (n.d.). Manufacturing and Non-Manufacturing Report on Business®. Retrieved from https://www.instituteforsupplymanagement.org/ISMReport/content.cfm?ItemNumber=10743&navItemNumber=12944

Kensho Technologies, Inc. (2016, June 27). Kensho Space℠ Index. Retrieved December 18, 2017, from https://indices.kensho.com/index/KMARS

Kensho Technologies, Inc. (2017, June 16). Kensho New Economies Index Methodology. Retrieved December 18, 2017, from https://indices.kensho.com/assets/methodology/kmars.pdf

Lockheed Martin Corp. (LMT). Income Statement. *Yahoo! Finance.* Retrieved from https://finance.yahoo.com/quote/LMT/financials?p=LMT

Mankiw, N. G. (2010). *Macroeconomics* (7th ed.). New York, NY: Worth Publishers.

Northrop Grumman Corp. (NOC). Income Statement. *Yahoo! Finance.* Retrieved from https://finance.yahoo.com/quote/NOC/financials?p=NOC

Satellite Industry Association. (2017, June). *State of the Satellite Industry Report 2017* (Rep.). Retrieved from http://www.sia.org/wp-content/uploads/2017/07/SIA-SSIR-2017.pdf

Space Foundation. (2016). *The Space Report 2016: The Authoritative Guide to Global Space Activity* (Rep.). Retrieved from https://www.spacefoundation.org/sites/default/files/downloads/The_Space_Report_2016_OVERVIEW.pdf

Space Safety Magazine. (2014). Space Economy. Retrieved from http://www.spacesafetymagazine.com/space-on-earth/space-economy/

Stock, J. H., & Watson, M. W. (2014). *Introduction to Econometrics* (3rd ed.). Essex, England: Pearson Education.

U.S. Bureau of Labor Statistics. (2017, November 17). About the Manufacturing Sector. Retrieved from https://www.bls.gov/iag/tgs/iag31-33.htm

Woolridge, J. M. (2013). *Introductory Econometrics: A Modern Approach* (5th ed.). Mason, OH: South-Western, Cengage Learning.

Observations on the reproductive biology of the darter fish Etheostoma kennicotti in response to gill parasite infections

Zeina Sleiman and Corinne Peacher
Department of Biological Sciences

Abstract – *Etheostoma kennicotti*, the stripetail darter, is found in streams in Tennessee, Ohio, Kentucky, Illinois, Alabama, Georgia, and Mississippi. The specimens for this study were collected in Estillfork in Jackson County, Alabama from August 2016 to June 2017 [12]. After collection and dissection, data were found to illustrate a peak reproduction period during the months of March to May 2017. The purpose of this study is to determine whether or not parasitic infection affected fecundity within the species as well as to contribute information for *E. kennicotti*, an otherwise poorly studied species. Parasitic load was found to be highest in the month of March and steadily decreased as the reproductive season progressed. Similar trends were found in the mean intensity of infection. There was a negative correlation between mean intensity and clutch size in that the clutch sizes increased into the month May, the end of reproductive season.

I. Introduction

Fecundity compensation is a non-immunological defense mechanism against parasite infections [11]. It is defined as a triggered response to parasitic activity by the use of an increased clutch size with a drawback of decreased size of the oocytes [8]. This may happen under the theory that the increase in fecundity has a lower energy cost than maintenance of an immune system [5]. The fecundity compensation may be a result of the *Aethycteron* species gill parasite infection in the host *Etheostoma kennicotti*, the stripetail darter.

Similar research with *Etheostoma flabellare* [8], a close relative of *E. kennicotti*, suggests that the Monogenean gill parasite, *Aethycteron moorei*, or a parasite of the same genus, may inhabit *E. kennicotti* as suggested in a study that compared two similar species and their microhabitats [7]. The assumption can be drawn due to the concept of the monogenean species' capability of shared microhabitats, with different preferences such as morphological attachment organs and an abundance of various parasites being the only restriction on niches and not interspecific interactions. We assume that an undescribed *Aethycteron* species inhabits the gills of the host, *E. kennicotti*, enabling us to determine if there is possible evidence of the fecundity compensation hypothesis.

The genus *Aethycteron* falls under Monogenea which is a phylum subclass of Trematoda, a Class that consists of primitive flukes with monozoic bodies and an affinity for fish [9]. This Class has no digestive tract or any internal cavity for the parasites' internal organs, instead the internal organs are encompassed in the parenchymatous tissue. The *Aethycteron* parasites attach to the gill tissues through an attachment organ comprised of hooks, typical of this subclass.

Trematodes have two different effects on fish through the causation of non-immunological defense: complete castration, or a reduction of the host's reproduction, instead of complete nullification [4]. *Trematodes* in one study apparently caused the reduction of reproductive output and physiological condition of mussels due to the parasites' castrating capabilities [3]. The capabilities of the host to have a compensatory mechanism created would enable the continuation of a species despite parasitic abundance or pressure, through fecundity compensation.

With the possibility of a non-immune defense mechanism in *E. kennicotti*, the host can be studied. Currently there has not been any extensive research done on this particular species. The only prior information available was that of *E. kennicotti's* habitat of hiding under rocks and underbrush in small creeks, which guided our finding and collection of the fish.

II. Materials and Methods

Collection and Storage of *Etheostoma kennicotti*

All *E. kennicotti* specimens were collected monthly for eleven months, August 2016 to June 2017, from Estillfork (34 54 38'N 86 10 04'W 437 m) in Jackson County, Alabama. The *E. kennicotti* were distinguished from other members of genus *Etheostoma* by a characteristic striped pattern on each of *E. kennicotti*'s caudal fin. The fish were euthanized

using 10 mL of 10% clove oil and ethanol solution for every 200-300 mL of water in the holding bucket of the collected fish. All samples were given an identification number and fixed individually in 10% phosphate buffered formalin.

Identifying Parasite and Count

The gills of each sexually matured *E. kennicotti* were extracted under a Motic K Series dissecting microscope at 50X by opening the outer gill flap with a probe and, with the use of a scalpel blade, making cuts around each of the gill arches to disconnect them from connective tissue. The gill arches were removed and observed under an Olympus SZ7 dissecting microscope. The eight gill flaps were flipped through and each *Aethycteron* parasite was counted and removed from the flaps. The parasites and gill arches were stored in corresponding ID tubes in 10% formalin. The parasite counts were used in calculating parasitic load to determine percentage of infection and mean intensity to determine if either gender was infected more heavily and in which months.

Body Size and Reproductive Data

Each *E. kennicotti* was measured in terms of somatic weight and standard length (SL). The somatic weight was taken before any dissection with the use of an Ohaus Explorer balance to 0.0001 gram. The SL was also done before dissection and measured from the snout to the caudal peduncle [7] and measured to the 0.001 mm.

Originally, dissections were limited only to specimens of 30mm length or greater on the basis of previous experiments on the larger species of *E. flabellare*. However, with finished dissections of all the collected *E. kennicotti* samples of 30mm length and longer, we observed a strong male bias. Thus, with an apparent sexual dimorphism, the dissections were adjusted to include specimens of 25mm in length and greater. This small change in procedure resulted in the dissection of a far greater number of female specimens, confirming our suspicions that a dimorphism related to body length between the sexes does exist. Unlike many other species of the genus *Etheostoma* that demonstrate full reproductive maturity at a length of 30mm, females of *E. kennicotti* exhibit sexual maturity at 25mm or less.

The pectoral fins were removed in order to ensure an easier and cleaner dissection. The primary incisions were made below the lower jaw of the fish, continued down the length of the abdomen, and terminated at the pelvic fins. The testes were located underneath the intestine and were attached to the stomach via mesorchium. Typically, the testes were translucent and small in size, which meant that their general location and connectivity within the abdominal cavity was crucial to identifying the reproductive organs.

In contrast to the testes, the ovaries of the females were quite large and were easily discernible from the surrounding organs. The gonads were weighed to 0.0001 gram upon removal and stored in tubes of 10% formalin. The ovary of an *E. kennicotti* may contain upwards of 20-30 mature oocytes. Photographs of all the gonads and the oocytes were made with the use of the Olympus SZX7 stereo microscope and extra illumination from a goose neck lamp. With the oocyte photographs, the Egg Helper program was used to count all oocytes and five oocytes of each developmental stage were measured. Depending on their stage of development, the oocytes progressed in color and size from small and nearly translucent to a bright yellow, indented orb approximately 1 mm in diameter.

III. Results

Once the mass for both the somatic body and the gonads were obtained, the gonadal weight values were used in conjunction with the somatic weight of the fish to determine the gonadosomatic index, or GSI, for each specimen. The equation used to calculate GSI:

Equation 1 - GSI

$$\frac{\text{Gonadal Weight}}{(\text{Total Somatic Weight} - \text{Gonadal W eight})} \times 100$$

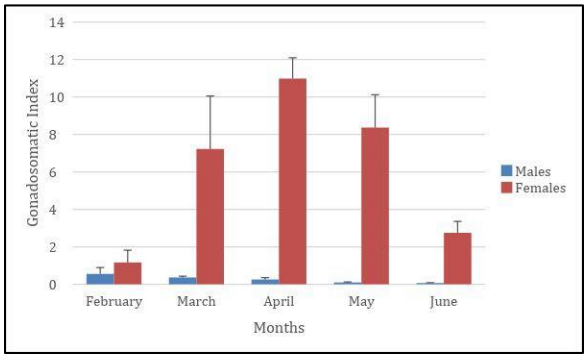


Figure 1: GSI
Through the usage of their GSI, as seen in Figure 1, there was a normal distribution of GSI between the months of February and June with April being the peak month of reproduction. Using this observation, these five months were the focus of this ongoing study. Error bars represent the standard error.

Through the extraction of the gills, fish found with at least one *Aethycteron* parasite were totaled and divided by the total number of fish collected for each month to determine the percentage of infection.

Equation 2 - Percentage of Parasite Load

$$\frac{\text{Total Number of Infected Fish}}{\text{Total Number of Fish}} \times 100$$

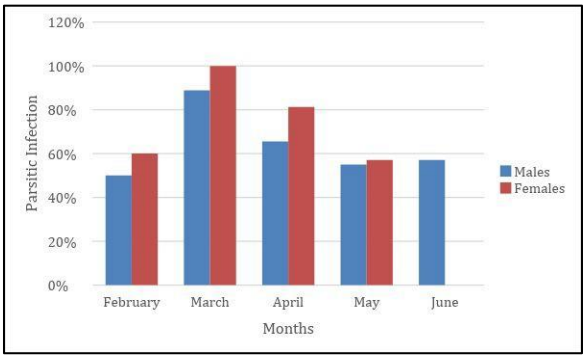


Figure 2: *Percentage of infection during reproductive season. The parasite load peaked in March and decreased drastically in April, then had an increase recovery in May.*

Determining mean intensity was done by totaling the number of parasites in the infected specimens and dividing the total by the number of affected fish per month.

Equation 3 – Parasite Mean Intesity

$$\frac{\text{Total Number of Parasites}}{\text{Total Number of Infected Fish}} \times 100$$

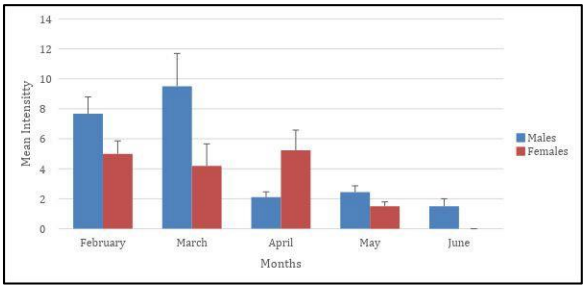


Figure 3: *Mean intensity of parasite load of male and female fish during peak reproductive season. The trend illustrates males holding a higher intensity for two out of three months with the exception being in April. Another trend seen in the mean intensity can be pictured to support the parasite load percentage in* ***Figure 2****, which holds a strong positive correlation. The trend of mean intensity is seen decreasing throughout the months portraying the correlation with the decreasing trend of the parasite load.*

The eggs in females were categorized into four different types: latent, maturing, mature, and mature ripening. After type classification, clutch size was determined to be the number of type III and type IV ooctyes. **Figure 4** shows the average in clutch counts in each month of the reproductive season.

Equation 4 – Clutch Count Average

$$\frac{\text{Total Number of Type III and Type IV Oocytes}}{\text{Total Number of Oocytes}}$$

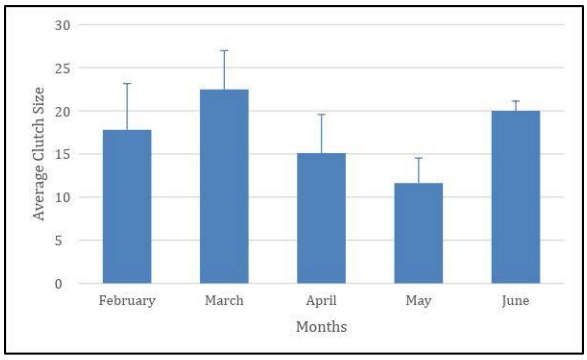


Figure 4: *Average clutch size with error bars representing the standard error.*

IV. Discussion

With a high diversity of the darter species, little research on the life histories of the host-parasite relationships has been conducted [5]. This is true of *E. kennicotti* and its relationship with the *Aethycteron* gill parasite, creating a line of research that can provide further evidence on whether the fecundity compensation hypothesis is true.

Due to the lack of research done on *E. kennicotti*, reproduction periods were initially only assumed. GSI values were first calculated to determine the effect of parasitic infection on reproduction patterns. GSI was determined and the trend portrayed in **Figure 1**, providing data that the reproduction peak periods are in March through May because of the female ovaries growing heavier with maturing oocytes.

Parasite abundance appeared to have a seasonal pattern in the host, *E. kennicotti*, due to their temperature specificity. Water temperatures in Estillfork ranged from 12° C in February to 25° C in June, but the life cycle of monogenean parasites are known to be temperature dependent with the optimal temperature range of 14° to 20° C [9]. Temperatures ranged from 16° C to 23° C throughout *E. kennicotti's* reproductive season, which largely correlates to the optimal temperature range for the reproduction of the monogenean parasite. As represented in **Figure 2,** the highest percentage of parasitic load occurred in the month of March and slowly decreased into May, which can be explained by the combined variables of optimal water temperature and host reproductive conditions, enabling the monogenean infection to peak in the month of March and then slowly decrease in May as water temperatures increased. The trend in **Figure 3** also confirmed this correlation with March having the higher mean intensity in males and slowly decreasing into the months of April and May.

According to Page [10], males guard the eggs during the reproductive season portraying a different behavioral pattern than the females, consistent with the discovered trends shown in **Figure 3** and **Figure 4.** The parasite *Aethyceteron* would have a higher rate of infection in males during the month of March due to optimal water temperatures and higher host activity.

Fecundity compensation is the post-infection mechanism of an organism's reaction to a parasitic infection. The change in reproduction rather than immunological activity is the key to identifying fecundity compensation, but we are yet unable to make a strong conclusion with *E. kennicotti*. Reproduction time and pattern of parasitic association can be confirmed. With such close association between reproductive timing in the host *E. kennicotti* and its *Aethyceteron* parasite, it can be concluded that the parasites have matched their reproductive patterns similar to their host to enhance higher success in parasitic infection due to the energy costs of reproduction within the host [1]. Further research is needed on *E. kennicotti* to confirm direct correlation between parasitic infection and fecundity.

References

[1] Adrian A.B, Holmes B., and Stallsmith B.W. (2012) Impact of a Gill Parasite upon the Minnow *Notropis telescopus. Southeastern Naturalist* 11(1): 35-42

[2] Baker, J. A. et al.(2015) Life-History Plasticity in Female Threespine Stickleback, *Heredity* 115, no. 4: 1–13, doi:10.1038/hdy.2015.65.

[3] Feminella, Jack W. (2008) Parasitic Mite and Trematode Abundance Are Associated with Reduced Reproductive Output and Physiological Condition of Freshwater Mussels, *Hydrobiologia* 610: 25–31, doi:10.1007/s10750-008-9419-8.

[4] Granovitch, A. I., E. B. Yagunova, A. N. Maximovich, and I. M. Sokolova. 2009. Elevated Female Fecundity as a Possible Compensatory Mechanism in Response to Trematode Infestation in Populations of Littorina Saxatilis (Olivi). *International Journal for Parasitology* 39 (9): 1011–19. doi:10.1016/j.ijpara.2009.02.014.

[5] Hanson, Robert H. (2013) Patterns of Infection by Monogenodians in an Assemblage of Darters, *Journal of Freshwater Ecology* 28: 3, 385-396.

[6] Heins, David C. (2012) Fecundity Compensation in the Three-Spined Stickleback Gasterosteus Aculeatus Infected by the Diphyllobothriidean Cestode Schistocephalus Solidus, *Biological Journal of the Linnean Society* 106, no. 4: 807–19.

[7] Kadlec, D., A. Šimková, and M. Gelnar. (2003). The Microhabitat Distribution of Two Dactylogyrus Species Parasitizing the Gills of the Barbel, Barbus Barbus. *Journal of Helminthology* 77: 317–25. DOI:10.1079/JOH2003183.

[8] Million, Kara M., Crissy L. Tarver, Sean Hipe, and Bruce W. Stallsmith. (2017). Does Infection by the Monogenean Gill Parasite *Aethycteron Moorei* Affect Reproductive Ecology of the Darter *Etheostoma Flabellare* in Mill Creek, Tennessee? *Copeia* 105 (1): 75–81. DOI:10.1643/CE-16-403.

[9] Olsen OW. (1968). Types of Monogenic Trematodes, in *Animal Parasites: Their Life Cycles and Ecology.* 199. Mineola (NY): Courier Dover Publications.

[10] Page, L. (1983) Handbook of Darters. T.F.H. Publications, Inc. USA. 271 p. 163

[11] Parker, Benjamin J et al., Non-Immunological Defense in an Evolutionary Framework, *Trends in Ecology & Evolution* 26, no. 5 (2011): 242–48, DOI:10.1016/j.tree.2011.02.005.

[12] Simon, T.P. and D.J. Faber. (1987) Descriptions of Eggs, Larvae, and Early Juveniles of the Iowa Darter, *Etheostoma exile* Girard from Lac Heney, Quebec. *Canadian Journal of Zoology* 65: 1264-1269.

THE UNIVERSITY OF
ALABAMA IN HUNTSVILLE

PERPETUA