LOGOS

A Journal of Undergraduate Research

Volume 9
Fall 2016

ISSN 2153-1560 (print)
ISSN 2153-1579 (online)

LOGOS
Honors College
Missouri State University
901 South National Avenue
Springfield, MO 65897
honorscollege@missouristate.edu

Missouri State
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Editorial Statement

LOGOS: A Journal of Undergraduate Research is dedicated to the publication of scholarship and artistry by Missouri State University (MSU) undergraduate students, including undergraduate students coauthoring with faculty. It is open to submissions from all undergraduate students at the university and conforms to the highest standards of scholastic integrity in a blind, peer-review process conducted by distinguished faculty and students.

The Missouri State Honors College sponsors *LOGOS*, and oversight and governance is provided by a faculty advisory board. The journal is produced by a managing editor, a chief editor, associate editors, and a student review board, all of whom are part of the Honors College.

LOGOS encourages submissions from all current or former undergraduate students of MSU who are seeking a professional venue for publication of their undergraduate research. Prospective contributors can contact the managing editor with questions about publication standards and the review process at Logos@missouristate.edu.

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Arts and Letters

Tawn Dickison

Influences

Abstract

In the spring of 2014, I spent two months in Taiwan as an exchange student. During my time there, I experienced a diverse culture, saw ancient artworks, and met heartwarming people. From these experiences, I created a body of work for my senior show and completed my Bachelor of Fine Arts in Ceramics degree in the spring of 2015.

Culture, art, and people were the greatest influences of my trip. I chose items to represent each area of influence and hand-built these pieces from porcelain. The people I met were quite delicate and graceful. They were beautiful to be around and a joy to spend time with. At times, their desire to communicate left me stunned. I chose large leaves to represent the gracefulness and gentle manner of the people.

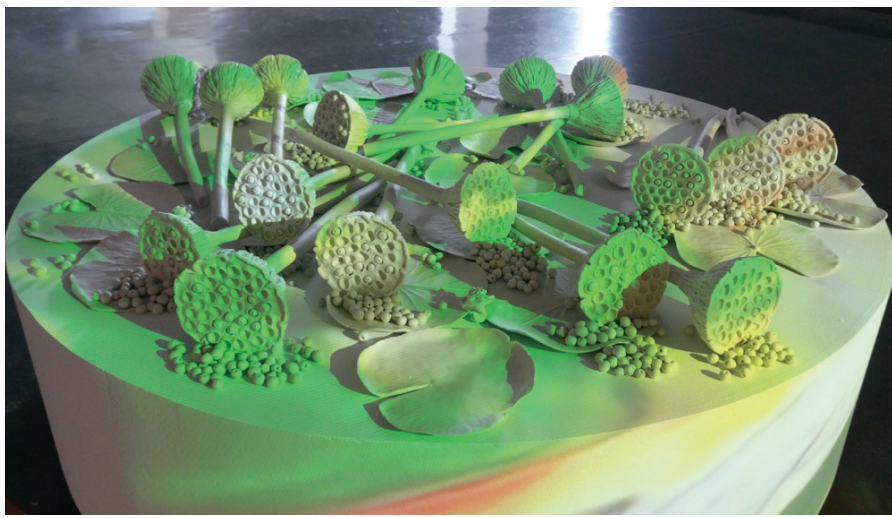
The lotus pod represents the art. Daily, I walked past a small pond with lotuses growing by the dozens. It was an amazing sight to see the lotus bloom and turn to seed in such a short time. In museums, I saw art I had never seen before. It was thrilling to see the lighthearted ceramic pieces of Picasso, the stunningly sensual lithographs of Man Ray, and the repetitive forms of Hsu Yunghsu.

I chose several different pieces to represent culture. The dominant piece created from porcelain was the dumpling. I ate round, half moon, flat, rectangular, and several other shapes of dumplings filled with pork and leeks. Another piece I chose to represent culture was a small Buddha figure. There were many colorful and intricately ornate temples that provided solitude for some and acted as a gathering place for others. Along with a small seedpod and a flower, I created a larger repetitive pattern from these pieces. In the interior of buildings in Taiwan, complicated designs were on the linoleum floors, walls, and ceilings.

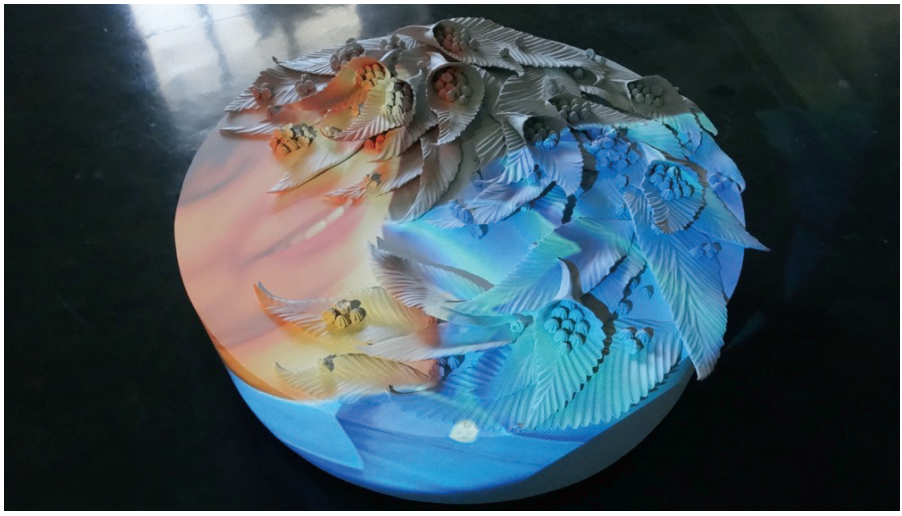
The porcelain pieces from each of the three areas of influence were arranged on three 4-foot round, 14-inch tall, white pedestals. Above each pedestal hung a projector, which projected a slideshow of photos I took while in Taiwan. These photos represented the memory of my time there. Since memories can be glimpses or foggy snapshots, I portrayed this quality by projecting portions of the pictures. Some photos had recognizable portions while others could only be interpreted as areas of color or gestural marks.

This visual representation of my experience has granted me the opportunity to show the depth of influence another country has had on my life. I indulged in this experience, and I tried to absorb everything around me. I created objects out of pristine white porcelain to convey the precious influences I now have in my life.

Culture. Photos I took of Taiwan float over porcelain pieces, both of which represent the culture I experienced.



Art. The photos I took of art while in Taiwan are projected onto the hand-made porcelain lotus. I had the pleasure of watching lotuses bloom and begin to yield seeds.



People. The gentle people I met in Taiwan are featured in the photos I took, which glide across the porcelain leaves. The porcelain pieces represent the kindness and gentleness the people showed me.

Sydney Gunter

Europa, Untethered

Abstract

"Europa, Untethered" tells the story of Europa, a Jovian moon discovered by Galileo in 1610. This free verse poem demonstrates what it really takes for someone to escape the gravitational pull of an abusive relationship, pick up the pieces, and re-empower him- or herself. Through a complex metaphor and an other-worldly setting, an unfortunate situation becomes relatable to those who have never faced it, and it paves the road to recovery for those who have. Europa serves as a reminder that even if it seems to defy the laws of physics, escape is possible.

The cracks of my surface still
struggle to hold me together.

He was the one who caused them—
The largest, the greatest, the *best*
planet with a thousand
beautiful moons trapped
in his orbit.
O Jupiter,
that bastard.

But what is a moon without a
body to orbit? An empty satellite.
Space is cold. *I* am cold.
Still made of broken ice—
If my core was once warmed
due to his gravity, is it lost
without him now?
So far from the Sun he's pulled me
and countless revolutions later
I still cannot forget—

A cruel giant with far too many
red storms swirling under his
exterior to *care* for anyone else.

He only sought to collect beautiful things;
he never wished to keep them warm.

Though I was one of the first,
I am no longer his or Galileo's.
Let the scientists ask how these
fissures formed; let me finally forget
the gravity that kept my skin from splitting.

Under these ultimately unchangeable sheets
of ice, frozen in space and time
I have a core of my own.
There are oceans in my veins,
in my fault lines.
Beautifully broken, the experts say.
I am a treasure. I am a discovery.
I am Europa,
untethered.

Janeshae Henderson

Permanent Fear

Abstract

"The one permanent emotion of the inferior man is fear—fear of the unknown, the complex, the inexplicable. What he wants above everything else is safety." - H.L. Mencken

A scar is a mark left on the skin by some sort of wound that replaces that damaged skin with fibrous tissue. Scars can be quite large and unattractive. I began this project thinking I could build confidence in people who were insecure about their scars. In the midst of photographing people, their stories of how they became scarred became my focus. The more I photographed scars, the more this project became about me, rather than the people being photographed.

My models have come to terms with what they survived. After hearing their stories, I question how I would react to such trauma. I have not endured tremendous pain—that is what I am afraid of. I have seen what can happen and the physical scars the experience can leave. The scar stands as a metaphor for pain. I am not afraid of the physical scar but the pain that is associated with it. Trauma does not discriminate. It can happen to any of us. This fear will never go away, but with this project, I am facing my fear through my camera.

Heart surgery. She is a twin, and she and her sibling were born prematurely. She had to have heart surgery as a baby.

Scoliosis. She has had two surgeries, one at age four and the other at thirteen, to correct the curvature in her back from scoliosis. She has several screws and plates in her back to keep her spine straight.

Totaled. She was in a car accident that was her fault. Her car was totaled, and she came out with several scratches, bruises, and scars.

Totaled. This is the same situation and accident from the above photo. She was left with this scar as well.

Curve. She has a 29-degree curve in her back from scoliosis, which causes constant pain. She cannot have surgery to correct it until the curvature hits at least 40 degrees.

Birth defect. He was born with only a thumb on his right hand, but the scar on his stomach was from a surgical procedure. It is so large because he began riding his motorcycle too soon after the surgery, so it split back open.

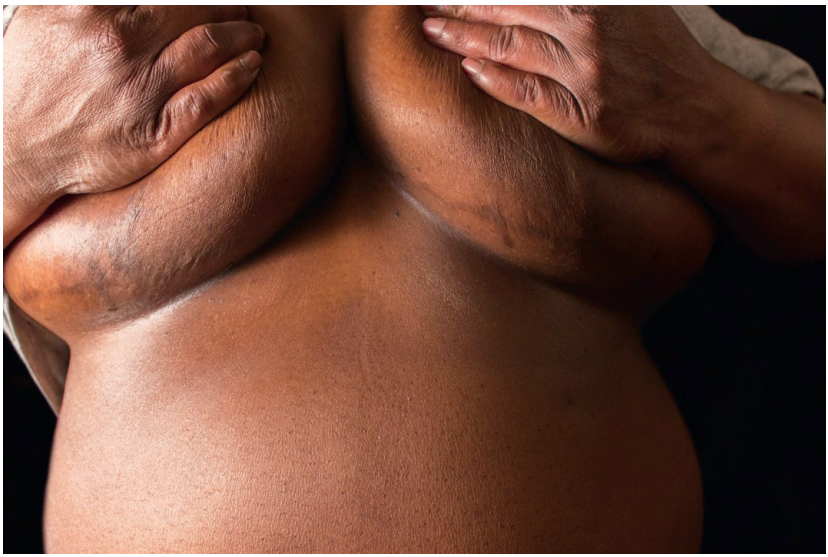
Double mastectomy with reconstruction. She had breast cancer, so she had a double mastectomy. Fat was brought from her stomach to reconstruct her breast.

Double mastectomy. She had breast cancer, so she also had a double mastectomy. She did not have reconstructive surgery afterwards. She now mows the lawn without a shirt.

Father. He has dealt with depression his whole life. At the young age of fifteen, he watched his father die in a hospital bed. He kept all of his emotions bottled up until he was twenty years old. He began cutting himself with razors just to try to feel something. The pain felt good and made him feel alive.

Three times. He was in a bad car accident when he was about 13 (now 19). Sleeping in the back seat when a drunk driver hit the car he was in, he was awoken by pain and his brother pulling him out of the vehicle. He passed away on three different occasions and had to be brought back to life. He then fell into a two-week coma.

Self-inflicted. There was not one specific incident that caused him to self-harm. He went through a lot as a young man and was very anti-social. Cutting himself was an emotional relief.



Breast reduction. Her breasts were 38DDDs before her surgery. They caused back pain and discomfort. Her surgery brought her to a 36C.

Car accident. His wound was so large that it would not be able to close on its own. Skin was taken from his thigh, so the open wound would heal.

Cory Powell

Home

Abstract

My work explores the private lives of young adults and college students. I have always been interested in photographing the people around me, especially as my circle of friends and people I surround myself with changes every year. Combined with an inherent interest in my friends and colleagues, I have always been interested in the notion of the home as a status symbol and how it is representational of the individual. Much can be gathered from the way a person lives. With these interests in mind, I started to document the living circumstances of young adults as they experience what it is like to live on their own for the first time.

College is a very unstable time for many people my age. It is not uncommon to move to a new apartment or house every year or even every semester. In these photographs, I explore the consequences of these transient living situations on the young people around me. Additionally, I explore how others have adapted their homes to fit their aesthetic and functional needs. The context of each person's home suggests something about the individual that I believe a simple portrait of that person on a nondescript background could not. My aim with this body of work is to understand more about the college experience outside of the school setting. Furthermore, I wanted to see how my friends and colleagues have made their homes their own as they near their last year of college.

Anya. Anya had thrown a house party a few days earlier and thought the balloons would be a nice element in the final image.

Brady. The critter on Brady's coffee table is a twenty-four karat gold-plated alligator named Buster. He received Buster as a Christmas present two years ago.

Carrie. Much of Carrie's apartment is bird-themed. Carrie also painted a mural of flowers on a wall in her kitchen.

James. James lives with his fiancé, Anya, in a small house they rent. On this occasion, James would only let me photograph him in this one spot.

Logann. On this particular day of photographing, Logann had a cold. As such, he was unaware of being photographed for much of the time leading up to this picture.

Shannon Wick

First Rules

Abstract

These poems explore different lessons I learned at a young age that helped me become an adult. They are partly fiction and partly autobiographical. In my first poem, I explained that there are times when an individual fails, but that doesn't mean the experience lacks meaning. The lesson in my second poem is that an individual cannot fix a loved one's depression. Lastly, I explore the idea of letting friends go in order to move on. Each poem deals with issues of self, relationships, and experiences that shape a person.

Sunflowers

This year I bought Russian Mammoths to plant
beside the shed. They can grow to a monstrous six feet,
but this summer they barely made it. Every season
I pick bigger ones, their blooms swelling
along with their need for attention.

I tilled the dirt, harder every year, more
earth beneath my fingernails. I planted more than ever
this time, white shed walls ready to brace them while they grew.
I pulled out the impetuous weeds and watered
twice a day, my back bent and aching. The dogs turned my ten into
six, then deer turned the six into three.

I planted broken sticks to protect my monsters. Their branches
stretched out, knobby claws scavenged from the yard. The broken stocks
of their felled siblings remained short beside them.
I defended my last three hopes, growing manic in the heat. By August,
I had to crane my neck to see their closed faces. When my numbers
dropped to two, I began to feel listless in tending them
while the calendar pages turned and summer
became next year's vacation.

A week after I left, they blossomed,
their faces open like the sun,
their bright green seeds uncovered. Yellow

with the warmth of the late summer light, they were
beautiful—
in the pictures my mother sent.
By the time I came home again, their
petals had withered. The next time I made the trip,
they were dead. Next year,
I'll plant American Giant Hybrids.

My Mother's Perfume

It has rotted far inside her, that black
stain, which spreads like spilled wine
on bedsheets. She works hard at it,
but even we, her children, cannot ignore
the bags under her eyes and the sharp timbre
in her once-soothing voice. We feel lost,
sitting at the kitchen table, not able to determine
what she needs. A hug won't do it, I don't think,
nor will a cup of her favorite coffee.

Through eyes that have not yet lost their innocence,
I see a woman dying like a flower. She wilts in front of me,
hands covering her eyes, petals curling in. I move towards her,
arms open for the warm lavender
that always accompanies her skin, ready to breathe in
her depression, take it on as my own.
Hands shake against my small back
and breath shudders in my hair.

Thank you, sweetie pie. I've got to do the laundry, though.

Warm eyes and a smile I remember, always
comforting and reassuring me as I go back to playing.
Later, when I slip into bed,
my sheets smell of lavender
and I hear crying in the hall.

Love—Your Best Friend

The weight of the broken snow globe rests heavy in my hand.
I trace my thumb over the gritty white letters telling me to
have a Merry Christmas. My finger catches on the sharp glass of
the shattered bulb and blood mixes with red glitter,
which has flaked off onto my hand. I draw in a shaking breath of
the new spring air, the cold wind moving around me.

I stare into the eyes of the miniature penguin and I pity him, his feet
fastened to the snowy floor with no room to move. When the globe
broke in my backpack, the water seeped into my books, leaving
a wrinkled path for me to trace. The wrapping paper tricked me,
hiding its fragile condition. My stomach twinges, I think back
to who gave me this present. I called her my best friend once,
but now, she won't speak to me. So I don't call her anything.
I grip my ruined present close to my chest
and drill my fingers in deep to block the painful
tightness that expands.
She ignores me nowadays, quiet as my fixed penguin.

The heat grows, my arm moves of its own accord.
The globe is hurtling through the air, my arm immediately
sore from the sudden movement. I watch the globe's
noiseless descent to the earth, hear the muted plop it makes
as it dips beneath the surface of the pond. I force myself
to breathe evenly as my stomach settles, though my hand pines
for the weight of the penguin and his snow globe prison.

Christina Woods

Hold

Abstract

This photograph was taken as a part of my individual project for Photography I, focusing on non-formal portraits of friends and family. I took it at my friends' apartment while waiting for my subject of the day. For a time during my individual project, I focused on taking photographs of my subjects' hands and the way their hands interacted with their surroundings or each other as a demonstration of their personalities and selves. In this situation, we were sitting on the couch and one friend decided to use another as a leg rest, which led to the moment depicted.

I am blessed to have stayed friends with the same group since freshman year. We have grown very close, and one of the things I was attempting to capture in the project was that kind of familial relationship; in this case, conveyed through physical affection. Physical contact is one of the most important human needs, and this photograph demonstrates one way it can be shown between friends and roommates.

Health and Human Services

Caleb Marshall & Dr. Erin Buchanan

Familiarity and Understanding of LGBTQ+ Hate Speech

Abstract

This study measured the relationship between the number of LGBTQ+ persons a participant knew and their perception of Lesbian, Gay, and Bisexual (LGB) hate speech. Prior sociological and psycholinguistic research precipitated this study's hypothesis that familiarity with non-heteronormative individuals affects one's perception of LGB hate speech. Moreover, it was hypothesized that familiarity with LGBTQ+ persons would positively correlate with perceived offensiveness of gendered hate speech. If such a correlation were found, it would suggest that one's familiarity with the queer community could influence perceived implicit meaning and eventual word choice.

This study included 36 participants and used a two-part survey. The first section of the survey measured participants' familiarity with the LGBTQ+ community and collected demographic information. The second section used a hierarchical rankings system and asked participants to rank anti-LGB hate speech offensiveness in different victim contexts. From the participants' survey responses, two scores were obtained: a measure of participants' personal distance from the LGBTQ+ community and their ratings of LGB hate speech. After collecting all survey responses, the two scores showed medium positive correlations in some categories, thus supporting the study hypothesis that participants with greater familiarity with the LGBTQ+ community would find gender-specific hate speech more offensive.

Introduction

In 2015, marriage enfranchisement was extended to the Lesbian, Gay, Bisexual, Transgender, and Queer-Inclusive (LGBTQ+) community in the United States (*Obergefell v. Hodges*, 2015). Federal protection for same-sex marriage changed the social landscape for non-heteronormative couples and relationships. For many, marriage equality in the United States signaled the end of an era categorized by discrimination, ignorance, and bigotry against LGBTQ+ persons. This change, propelled by the backlash of Proposition 8 in California, has even caused some to question if the era of closeted sexuality and open discrimination is over in North America (Weber, 2015).

Studies performed in rural areas of the country, however, have shown that discrimination against the LGBTQ+ community still exists in isolated regions, especially those with a small population of "out" LGBTQ+ individuals (Griffin, 2015). Moreover, in situations involving hiring new employees,

Tilcsik (2011) found that openly gay men were likely to face employment discrimination from places that focused on stereotypically male, heterosexual traits. Both studies found that systemic discrimination leads to an in-group/out-group structure which further ostracizes LGBTQ+ persons. This problem is confounded by stereotype homogeneity within minority demographic groups, defined by Brown-Saracino (2015) as the pressure within minority communities to conform to an identity-presentation which resembles one's presenting minority. For example, Brown-Saracino (2015) studied variations within lesbian communities in four separate cities and determined that within groups, identity presentation is significantly more uniform when compared to identity presentation in other lesbian communities.

As demonstrated, previous studies have shown that geography, demographics, and community boundaries in some part affect the external views and internal self-perception of minority groups. Moreover, established research has suggested that rural communities which focus on stereotypically masculine qualities often have higher rates of sexual-identity discrimination. Springfield, Missouri is an example of a small midwestern city surrounded by rural farmland. In April 2015, Springfield was highlighted in national news for its repeal of anti-discrimination laws protecting some civil rights of LGBTQ+ persons living within the city limits. The anti-discrimination ordinance, which had been passed by the city council in October 2014, was repealed by a narrow popular vote on April 7, 2015. Shortly after the repeal, news providers such as *Time Magazine* (Steinmetz, 2015) and *The New York Times* (Yokley, 2015) covered the repeal. This widespread media coverage led to national controversy as more progressive areas of the country, many of whom had passed similar pro-LGBTQ+ ordinances, questioned the motivation, character, and rationale of the Springfield repeal.

The controversy surrounding the Springfield repeal demonstrated the spectrum of opinions on LGBTQ+ rights in relation to an isolated event and is especially relevant in our understanding of part of this particular sample, as well as its impact on national news. Since group opinions on LGBTQ+ rights can be influenced by social factors such as location and community norms, how individual opinions on queer issues evolve must be addressed not only from a psychological research standpoint but also within the context of the perceiver's social environment.

This study was designed to test how one's familiarity—defined as the number of LGBTQ+ individuals a participant knew—affected perception of similar LGB hate speech. Familiarity was chosen for this study because of prior research suggesting that both social influences and familiarity can change personal opinions on issues related to the LGBTQ+ community. Mere exposure

to gay and lesbian persons increases support for gay rights and positive attitudes (Garretson, 2015). By using hierarchical word ranking, this study tested whether a personal factor like familiarity could affect perception of a term's implicit meaning, which is defined by Sagi and Dehghani (2014) as the moral, social, and emotional loading of and schemas surrounding a word or term.

Because of the subjective nature of hierarchical ranking, we theorized that participants' scoring of synonymous terms could be used to help parse one aspect of implicit meaning: offensiveness. This assumption was a reaction to Sagi and Dehghani's (2014) work on understanding how moral rhetoric was used in different texts. They used latent semantic analysis, a computational text tool, to understand the moral strength of words often used in context together. For example, they found an increase in morally-associated words to the term *mosque* after the debate of building a mosque close to Ground Zero in New York City (Sagi & Dehghani, 2014). Although Sagi and Dehghani analyzed the moral loading of words and phrases in rhetorical context, the content of this study built on their idea that presenting terms with associated context allowed for clearer analysis of implicit meaning as tied to familiarity with the LGBTQ+ community.

Method

This project distributed a two-part survey over social media. The first section asked participants for their basic information (gender, age, etc.) and the number of LGBTQ+ individuals they knew personally; the secondary section had participants rank terms typically associated with the LGBTQ+ community in order from least to most offensive. This survey was designed around the theory that participants with larger networks of gay acquaintances would more negatively rank specific, gender-oriented hate speech over generic hate speech. Also, by using social media, this survey targeted a variety of geographic locations, such as urban centers and rural areas across the United States, which would provide cross-community input, thus avoiding the stereotype homogeneity within one location as presented by Brown-Saracino (2015). By sampling from varied locations, this study was able to avoid place stereotyping and develop a nuanced analysis of LGB hate speech.

Participants

This study made use of an online survey disseminated via Facebook and email links to 36 individual participants. Fifteen participants were from an undergraduate honors seminar at Missouri State University. These participants were chosen using convenience sampling, and they accessed the survey through an

email link disbursed via the college email server. The remaining 21 participants accessed the survey through a link distributed within a group of past participants at the Interlochen Arts Festival, a national arts program which draws participants from across the country. The author was a member of said group; however, he was not personally acquainted with the majority of persons within the group. Twenty-six participants identified as female, and 10 identified as male. The majority of participants were 18 or younger.

Materials and Procedure

Before viewing the survey, participants were informed they would see potentially offensive speech and that they could end the survey at any time with no penalty. The online survey was divided into two distinct sections: demographic information (from which the independent variable was drawn) and linguistic ranking of LGB slang (from which the dependent variable was drawn). The first section asked participants to provide their gender identity, age, and familiarity with members of the LGBTQ+ community. Questions pertaining to participant demographic and possible participant responses can be found in Appendix A, Table A1.

The second section contained five questions, four of which asked the participants to rank the "offensiveness" of 10 modern and historic LGB slurs within the context of differing sexualities (a heteronormative man/woman, lesbian, and gay man). All rankings were hierarchical, asking participants to rank terms against each other cardinally instead of a sliding scale. For example, all participants were asked to rank how offensive they found the terms "sissy", "queen" and "f-ggot" alongside seven other words. Identical sets of words were used across both sexuality variants. Adjustments were made according to gender when explicit meaning was required ("tomboy" was used in place of "sissy" for the female variant). For a complete list of terms utilized and their corresponding victim identities, see Appendix A, Table A2.

Results

Data Analytic Conceptualization

The purpose of the study was to measure the correlation between the number of LGBTQ+ individuals a person knew (*Q*-factor) and their perception of LGB hate speech (*R*-factor). In order to determine the *R*-factor of each word, participants were asked to rank the same word four times with different target victims in mind: a heteronormative man/woman, lesbian, and gay man. Because the terms presented had similar linguistic function, difference in par-

ticipant rating allowed this study to measure one aspect of implicit meaning—moral loading of the concept of offensiveness—and correlate this meaning to participants' familiarity with LGBTQ+ persons. Not only did this control for contextual bias within subjects' responses, it also provided an insightful look into how perception of sexuality affects the implicit meaning of hate speech.

In comparing participants' hierarchical ranking of words across both heteronormative and non-heteronormative circumstances, one is able to deduce the contextual offensiveness of individual terms more accurately and observe how familiarity affects perception of offensiveness. This study measured this relationship by having participants hierarchically rate a strongly-gendered term ("fai-y"/"dy-e") and a historically gender-neutral term ("f-ggot") alongside eight placebo hate-speech terms. For statistical analysis, linear correlations were calculated between these word rankings and familiarity for each participant by the term presented in the study. Correlations indicate the degree of relatedness between two variables, such that positive correlations indicate a simultaneous increase in variables, and negative correlations indicate that as one variable increases, the other decreases. However, the main focus in this paper was the comparison of gendered terms to a baseline, using Fisher's r-to-z transformation (Fisher, 1915). This procedure determines if correlations are significantly different, thus indicating a difference in strength of relationship between variables. We use Cohen's (1988) terms to define small (r = ±.10), medium (r = ±.30), and large (r = ±.50) effects.

For each of the four ranking questions, the correlation between individuals' ranking of "f-ggot" (R-factor$_{\text{f-ggot}}$) and familiarity (Q-factor) was the baseline of the study [r_{baseline} = correlation(Q-factor, R-factor$_{\text{f-ggot}}$)]. This term was chosen because it has a history of being directed toward the LGBTQ+ community as a whole, and while one may believe it to only apply to homosexual men, the concept originated as a derogatory term for women (Russo, 1981; faggot, n.d.). The dependent variable of this study was the correlation of familiarity to ranking of the gendered terms [$r_{\text{dependent}}$ = correlation(Q-factor, R-factor$_{\text{gendered-term}}$)]. This method of difference scoring postulated four dependent variable correlations: Heteronormative male ($r_{\text{fai-y/het.}}$), Heteronormative female ($r_{\text{dy-e/het.}}$), Non-heteronormative male ($r_{\text{fai-y/non-het.}}$), and Non-heteronormative female ($r_{\text{dy-e/non-het.}}$). All dependent variable correlations were based on the average participant ranking of presented gendered terms. By subtracting each baseline correlation from its corresponding dependent variable correlation, the final correlation (r_{final}) was determined ($r_{\text{final}} = r_{\text{dependent}} - r_{\text{baseline}}$). See Table 1 for correlation and difference scores as well as their Z-score and p-value. Results are discussed using a $p < .05$ criterion for statistical significance.

Table 1: Averaged Correlations Between Familiarity and Survey Ranking

Target population	Baseline	Gendered	Difference	*Z*-scores	*p*-values
HN Man	-0.29	0.40	-0.69	-2.96	<0.01
HN Woman	-0.05	-0.10	0.05	0.22	0.82
NHN man	-0.24	0.20	-0.44	-2.05	0.04
NHN Woman	0.09	-0.19	0.28	1.29	0.20

Note. These are the averaged values of correlations between familiarity (*Q*-factor) and survey ranking (*R*-factor) with their respective *Z*-scores and *p*-values.

Correlation Results

Within participant responses to heteronormative ranking, there were several moderate correlations between *R*/*Q*-factor. For example, participants with a higher *Q*-factor tended to view the baseline term "f-ggot" as less offensive when directed at a heteronormative man than other words offered. However, participants with higher familiarity scores were likely to rank the gendered term "fai-y" as more offensive than the baseline $r_{\text{f-ggot}}$ when used in reference to a heteronormative man. When the $r_{\text{f-ggot}}$ score was subtracted from the $r_{\text{fai-y}}$ score, a large negative correlation remained ($r_{\text{final/het. male.}}$ = -0.69). This implies participants with higher familiarity scores could be expected to rank presented gendered terms as significantly more offensive when compared to the study's baseline rating (*R*-Factor$_{\text{f-ggot}}$).

Similar correlations did not appear in the context of female victimization, which implies there was no significant relationship between participants' familiarity with LGBTQ+ and their ranking of presented terms in the context of victims perceived as female. There was little correlation of familiarity and ranking between both "f-ggot" and the more gendered term "dy-e." For individual participant responses, see Figure 1.

Correlations within participant responses to non-heteronormative individuals were less pronounced than those within the heteronormative groups. When ranking words addressed at gay males, the gendered term "fai-y" had the strongest correlation when compared to its baseline. When the $r_{\text{f-ggot/non-het. male}}$ score was subtracted from the $r_{\text{fai-y/non-het. male}}$ score, a moderate correlation remained. Like the heteronormative group, female victimization was again characterized by low *R*-factors. For graphical representation of individual participant responses, see Figure 2.

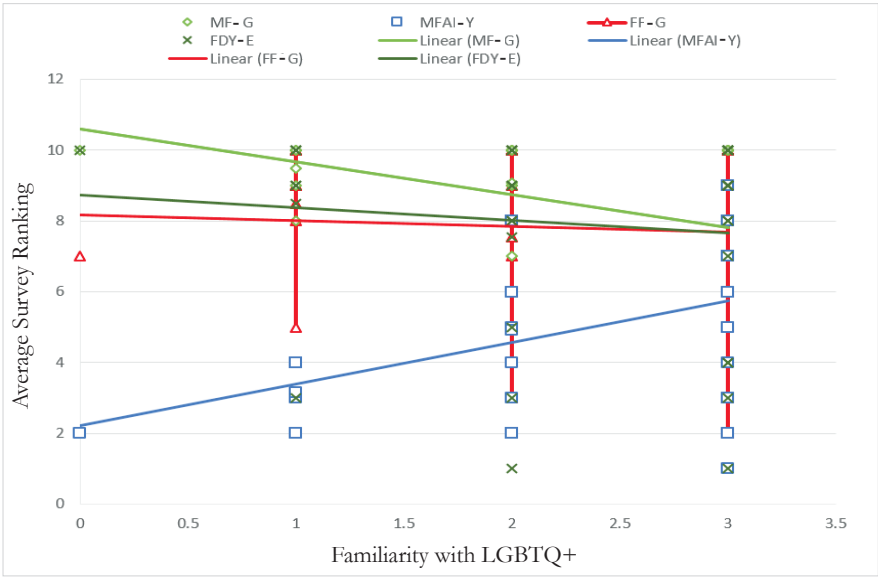


Figure 1. Participant rankings with regression lines for heteronormative sub-group responses. This scatterplot represents each person in the study; however, given the limited range of the scale, individual dots overlap. Regression lines are provided for visual reference.

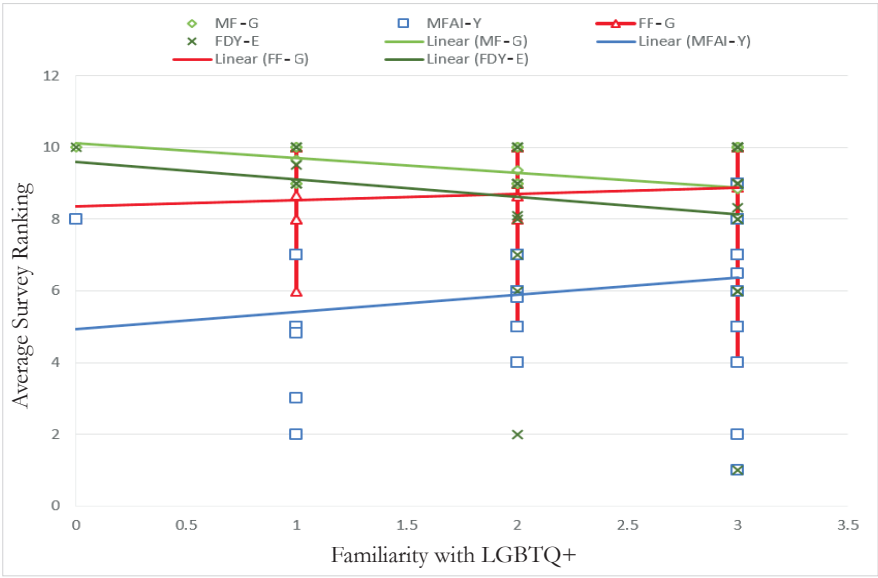


Figure 2. Participant rankings with regression lines for non-heteronormative sub-group responses. Again, the dots in this graph overlap due to the limited range of scores in this study. Regression lines are provided for visual reference.

Discussion

This study suggested a correlation between the number of LGBTQ+ persons an individual knew and their perception of LGB hate speech. The results suggested perceived gender and sexual orientation of hate-speech victims change this correlation. Within both the study's heteronormative and non-heteronormative sub-groups, the correlation was significantly stronger (larger, given Cohen's standards) when referencing male victims as opposed to female victims of hate speech. This result implies that when victims are perceived as male, strongly-gendered hate speech is viewed as more offensive than when the victim is perceived as female. Moreover, when rating hate speech directed at heteronormative victims, the correlation between the independent variable (familiarity to LGBTQ+ community) and dependent variable (individual speech ranking) was larger when contrasted with the non-heteronormative context's rankings. This finding implies participants with higher familiarity scores tended to rank gendered terms as more offensive than non-gendered terms.

These results support this study's hypothesis: namely, that the familiarity with LGBTQ+ persons influences perception of LGB hate speech. However, this study's results demonstrate the complexity of hate speech's implicit meaning. Judging from participant responses, it seems that LGB hate speech is subject to varied social forces, such as perceived gender, sexual orientation, and personal familiarity. Together, these social identifiers form elements of hate speech's implicit meaning, such as offensiveness. Though formally, terms such as "f-ggot," "dy-e," and "fai-y" are consistently classified as hate speech, the variability of participants' hierarchical rankings shows a diverse and nuanced view of participants' understanding of implicit meaning. As a sub-unit of English vocabulary, this study suggests LGB hate speech terms tend to have surprisingly flexible implicit meaning in spite of the individual terms' strict formal definitions.

From a societal viewpoint, this information could be used to help understand how LGBTQ+ visibility within society influences individual understanding, tolerance, and education with regards to sexual orientation and gender identity. Since this study seems to suggest that familiarity with the LGBTQ+ community does indeed alter linguistic perception, it would be reasonable to assume that the presence of out gay, lesbian, and non-binary individuals within a given community could change perception. In the future, further psycholinguistic investigations could explore how demographic and geographical communities respond to the presence of out LGBTQ+ persons in an attempt to understand how visibility of the LGBTQ+ community impacts

LGBTQ+ rights and issues. This research is especially crucial in the context of historical views of homosexuality and could potentially be integrated with new ways to educate others about sexual prejudice (Kite & Bryant-Lees, 2016).

Within this study, certain limitations exist. Namely, the sample size was less diverse than anticipated, and the survey was limited to only 10 questions. In further studies, this research should be expanded to include both wider sample studies (statewide/national level) and more focused sample studies (within individual high schools, socio-economic brackets, etc.) to allow this research to be extrapolated to more diverse populations. If the study were to be replicated, it would be worth including a third section on gender identity (male, female, transgender male, transgender female, and non-binary) to better understand the discrepancies found in this preliminary study within its pre-fabricated contexts.

Studying the language surrounding minority communities provides workable data on the societal, personal, and cognitive processes which characterize these groups and persons. Quantitative, psycholinguistic research is essential when engaging complex social groups. Research similar to this study's analysis of LGBTQ+ language should aim not only to analyze the data which presents itself, but also to use a mathematical structure to provide targeted analysis to their research findings (Sagi & Dehghani, 2014). As future studies deal with more complex, fluid aspects of queer culture, quantitative analysis can provide not only an accurate look at specific functions of LGBTQ+ language, but also the means by which to deconstruct queer theory from an empirical, non-biased viewpoint.

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Appendix A

Participants within this study's survey were asked to answer four questions regarding their demographics. The questions were about age, gender identity, religious affiliation, and familiarity with LGBTQ+ persons. Possible responses to these questions can be found in Table A1.

Within this study's survey, participants were presented four different contextual cues with corresponding word lists for ranking. These questions included the following text: "Rate the following words (least to most offensive) with the assumption that they are directed towards a [sexual identity marker]." To identify gender and sexual identity, four phrases were substituted for "sexual identity marker" in the previous statement: straight man, straight woman, gay man, and lesbian woman. In Table A2, lists of hate speech terms presented in the study can be found.

Table A1: Demographic Survey Questions

Question presented to participants.	Age	What is your Gender Identity?	Do you identify with any of the following religions? Please select all that apply.	How many LGBTQ+ people do you personally know?
		I identify as male.	Christianity	
		I identify as	Judaism	
	>18	female.	Islam	0
Possible	18–29	I identify as	Buddhism	1–3
Response 1	30–44	neither male nor	Hinduism	3–7
	45–59	female.	Not Religious	8+
	60+	I prefer not to	Agnosticism	
		answer.	Atheism	
			Other	

Note. These are the demographic questions presented in this study's survey organized by question type and possible responses.

Table A2: LGB Hate-speech Survey Terms

Functional use of the word in study's analysis	Heteronormative and Non-heteronormative Man	Heteronormative and Non-heteronormative Woman
Baseline	F-ggot	F-ggot
Gendered Term	Fai-y	Dy-e
Placebo	Pansy	Butch
Placebo	Sodomite	Tomboy
Placebo	Sissy	Lesbo
Placebo	Gay	Femme
Placebo	Twink	Lesbian

Note. These are the LGB hate-speech terms that were presented in the survey. They were organized by context and function within the study.

Mary Kranick

The Effect of Limb Length or Total Body Height on Maximal Muscle Strength

Abstract

The purpose of this study was to determine what effect limb length and height had on maximal muscle strength in an untrained population. This was conducted during independent study for a senior seminar. Thirteen individuals from Missouri State University and the Springfield, Missouri, area participated in the study (seven men and six women, ages 20–28 years). The participants were separated into two groups: active and sedentary. In a single session, subjects performed an aerobic warm up and found their five-repetition maximum on bench press and on leg press. This was followed by a cool down period. Anthropometric data, such as height, weight, femur length and circumference, and humerus length and circumference, were then taken. For males, limb circumference and height were determining factors in muscle strength. Females did not see any significant results.

Introduction

A common statement around gym message boards is that shorter individuals have an advantage over taller individuals on the bench press and other lifts. The idea is that taller lifters have to move the bar a greater distance, and thus do more work. Shorter people claim they have no advantage because a longer limb allows for a greater length of muscle. In powerlifting, many of the top athletes have a similar body type: mesomorphic or endo-mesomorphic (Keogh, Hume, Pearson, & Mellow, 2007). It is commonly accepted that individuals with a large chest and short arms tend to do well in the bench press, individuals with shorter legs tend to be better at squat, and longer arms are better at dead lifts when compared to their peers (Mayhew, McCormick, Piper, Kurth & Arnold, 1993). Because of this, it could be and has been hypothesized that shorter individuals with a mesomorphic body type may have an advantage when it comes to lifting. Much of the human body acts as a third-class lever. Biomechanical principles for third-class levers establish longer levers require more torque to lift a load. Thus, it would appear individuals who are shorter or who have smaller limbs would be at an advantage when performing bench press and squat exercises compared to taller, longer limbed individuals (Keogh et al., 2007). Taller individuals require a greater amount of work to lift the bar a longer distance in addition to having a longer lever arm requiring more torque application.

The purpose of this study was to determine the relationship between limb length and maximal muscle strength in untrained individuals. Based on previous studies, it was expected taller people would not be able to lift as much as their shorter counterparts if both parties were untrained. It was important for the subjects to be untrained so all subjects were at the same baseline. If the individual was actively participating in a weight training program, the differences in strength could be attributed to the strength program instead of limb length, adding an unnecessary variable.

Methods

Participants

Prior to working with any participants, approval was given by the Institutional Review Board to work with human subjects. This study was open to college-aged individuals from Missouri State University and the surrounding communities. Exclusion criteria included current regular weight training as defined by the American College of Sports Medicine as resistance training on two or more days per week (Garber, Blissmer, & Deschenes, 2011). The participants were separated into two groups: those who were considered active (participated in 150 minutes of moderate-intensity activity each week) and those who were considered sedentary (not meeting the active criteria of participating in 150 minutes of moderate-intensity activity each week). The purpose was to determine if an active population that did not participate in strength training would produce different results from a sedentary population. For example, if someone was a runner, they might have different leg press results from someone who is sedentary due to the development of the lower body muscles from the running program. Thirteen individuals participated in the study (seven men and six women, ages 20–28), ten of whom currently attended Missouri State University. Seven individuals were considered active (two females and five males), and six individuals were considered sedentary (four females and two males). All participants gave written informed consent before the start of the study.

Anthropometric Data

Each participant had several measurements taken prior to the beginning of the maximal strength test. First, height was measured to the nearest half-inch using a standard height gauge, and then, this measurement was converted to meters. Then, weight was measured to the nearest pound using a mechanical scale and then converted to kilograms. Next, limb length of the humerus and

femur was measured. Humerus length was measured from the greater tubercle of the humerus to the lateral epicondyle of the humerus. Femur length was measured from the greater trochanter of the femur to the lateral condyle of the femur. Finally, limb circumference was measured at the midpoint of the humerus and the femur's total length.

Bench Press Test

The five repetition maximum (RM) bench press strength was measured using a free-weight Olympic bar and plates. Typically, a one repetition maximum is considered the gold standard in determining maximal muscle strength. However, due to the inexperience of the population in this study, a one repetition maximum test is considered contraindicating (Kelly et al, 2015). Inexperienced lifters were instructed in how to perform the lift correctly before beginning. The subject gripped the bar at slightly wider than shoulder width. A spotter was present at all times. Each subject performed one warm-up set. One repetition was considered lowering the bar slowly to the chest and then fully extending the arms. After a warm-up set, the initial weight chosen was estimated from previous history if it existed, or from input from the subject. The subject then performed five repetitions of the weight. After two to three minutes of rest, additional weight was added until the subject could not perform five repetitions. The five RM was determined within six attempts to avoid exhaustion.

Leg Press Test

The five RM leg press strength was measured using a seated leg press machine. The seat was adjusted for each participant. Inexperienced subjects were instructed how to perform the exercise correctly before beginning. Each subject performed one warm up set. After a warm up set, the initial weight was chosen relative to the subject's body weight. The subject performed five repetitions of initial weight. After two to three minutes of rest, additional weight was added until five repetitions could not be completed. Some subjects maxed out the leg press machine. For those subjects, they performed the maximum amount of weight allowed by the machine for as many repetitions as possible. A five RM was then determined using the following equations: 1RM (kg) = Wt (kg) * (1 + (0.033 * # reps)) & 1RM (kg) = 1.069 * Rep Wt (kg) + 8.2. The first equation was used to solve for the one RM. The determined one RM was then used in the second equation to determine what the five RM should be. These equations were used for all of the males in the study except for one individual whose five RM was able to be determined without maxing out the machine.

Data Analysis

Pearson correlation coefficients were computed across all variables separated by sex. This measures the relationship between any two variables and is indicated by the value *r*. This value can range from negative one to positive one. A positive number indicates a positive correlation, while a negative number indicates a negative correlation. The closer the absolute value of the number is to one, the greater the strength of the correlation. The statistical significance was also determined. This indicates if the findings can be explained by random chance based on the population that was studied or by actual differences that occured. A *p*-value of less than 0.05 is considered significant. This means that there is a 5% chance that such results could have occurred at random and do not accurately reflect the population. Any *p*-value less than 0.05 can generally be used to draw conclusions about individuals outside of those in a study.

Results

Table 1: Male Characteristics

Variable	Mean	Standard Deviation	Range
Height (meters)	1.87	0.08	1.72–1.98
Weight (kg)	96.29	23.15	68.18–90.00
Humerus length (cm)	35.14	1.07	34.00–36.00
Humerus circum. (cm)	32.37	3.86	26.00–38.00
Femur length (cm)	53.00	2.45	50.00–57.00
Femur circum. (cm)	60.59	6.35	54.00–70.00
Bench press (kg)	66.23	13.40	50.00–88.63
Leg press (kg)	289.95	58.93	209.09–376.45

Note. These are the descriptive statistics for the seven males who participated in the study. Men had a greater mean than females for all values.

Table 2: Female Characteristics

Variable	Mean	Standard Deviation	Range
Height (meters)	1.67	0.05	1.62–1.72
Weight (kg)	69.62	20.91	50.91–100.00
Humerus length (cm)	30.00	2.61	26.00–33.00
Humerus circum. (cm)	29.50	5.89	25.00–38.00
Femur length (cm)	46.33	4.63	42.00–53.00
Femur circum. (cm)	54.00	8.32	46.00–65.00
Bench press (kg)	27.27	2.87	25.00–31.82
Leg press (kg)	154.54	34.40	109.10–200.00

Note. These are the descriptive statistics for the six females who participated in the study.

Table 3: Data for All Subjects

Subject	Gender	Active	Height (m)	Weight (kg)	Bench Press (kg)	Leg Press (kg)	Femur Length (cm)	Femur Circum. (cm)	Humerus Length (cm)	Humerus Circum. (cm)
A	female	yes	1.67	59.09	29.55	176.90	49.00	51.00	33.00	27.00
B	female	no	1.65	50.91	25.00	108.86	43.00	46.00	30.00	26.00
C	female	no	1.62	100.00	25.00	117.93	42.00	65.00	26.00	38.00
D	female	no	1.62	53.64	31.82	199.58	42.00	48.00	28.00	25.00
E	female	yes	1.72	62.27	27.27	163.29	49.00	50.00	32.00	25.00
F	female	no	1.72	91.82	158.76	53.00	64.00	31.00	31.00	36.00
G	male	no	1.91	135.45	88.64	375.57	57.00	70.00	36.00	38.00
H	male	yes	1.98	95.00	75.00	347.91	55.00	68.00	36.00	34.00
I	male	no	1.87	117.27	70.45	312.98	52.00	62.00	34.00	35.00
J	male	yes	1.72	68.18	50.00	208.65	52.00	54.00	34.00	26.00
K	male	yes	1.80	76.82	61.36	250.84	54.00	55.00	36.00	30.00
L	male	yes	1.89	92.73	65.91	271.70	50.00	58.00	36.00	32.00
M	male	yes	1.83	88.64	52.27	257.64	51.00	57.00	34.00	31.50

Note. Originally, all data was grouped together and all variances accounted for were due to gender differences, such as males generally being larger and stronger than their female counterparts. Due to too small of a sample size when accounting for gender, a regression analysis was unable to be run. Similarly, when accounting for biological sex and activity level, the sample size would be too small to draw conclusions about the active/non-active differences.

Males

For males, limb circumference appeared to be the determining factor in natural strength. This is illustrated in Figure 1 and Figure 2; the line representing circumference (for both humerus and femur, respectively) indicates a direct relationship between limb circumference and strength. Bench press was significantly correlated at the 0.01 significance level with femur circumference (r = 0.919, sig. = 0.003) and humerus circumference (r = 0.903, sig. = 0.005). This speaks to body size being a strong factor in determining strength. Individuals with large arms and legs were likely to be stronger than those with smaller girth of limbs. Bench was also significantly correlated at the 0.05 level with height (r = 0.759, sig. = 0.048) and weight (r = 0.866, sig. = 0.012). Leg Press was significantly correlated with femur circumference (r = 0.980, sig. = 0.001), humerus circumference (r = 0.948, sig. = 0.001), height (r = 0.749, sig. = 0.013), and weight (r = 0.872, sig. = 0.010). Again, these results point to body size influencing natural strength. Bench press and leg press were both correlated with each other (r = 0.950, sig. = 0.001).

Females

For females, the only significant correlations occurred between leg press and bench press (r = 0.866, sig = 0.026), femur length and height (r = 0.918, sig = 0.010), and weight with femur circumference and humerus circumference. This results speak more to overall body sizes than to what was expected to be found. For example, it is logical to expect a longer femur length be associated with a taller female. No significant results were found between limb length/circumference and bench press/leg press results.

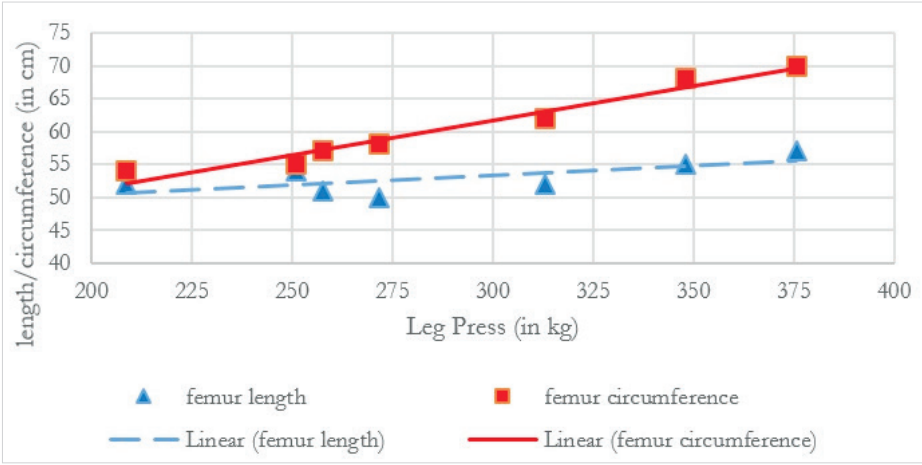

Figure 1. Leg press vs. femur length/circumference in males.

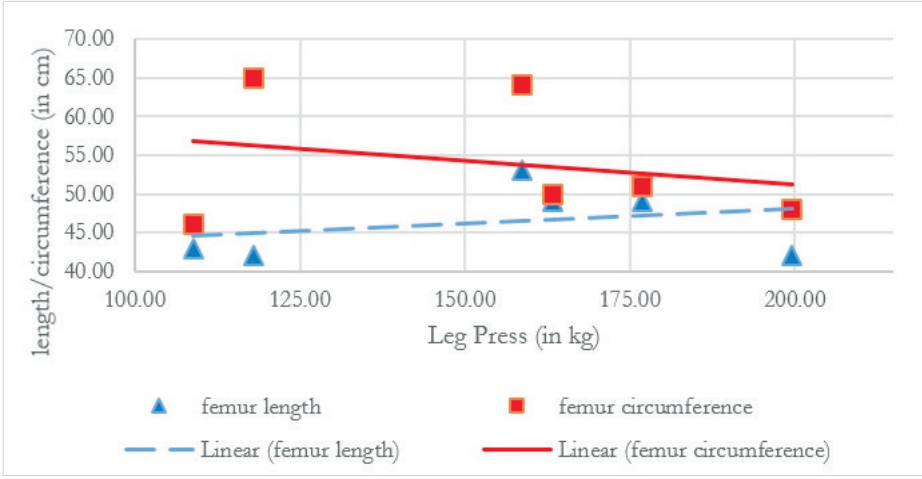

Figure 2. Leg press vs. femur length/circumference in females.

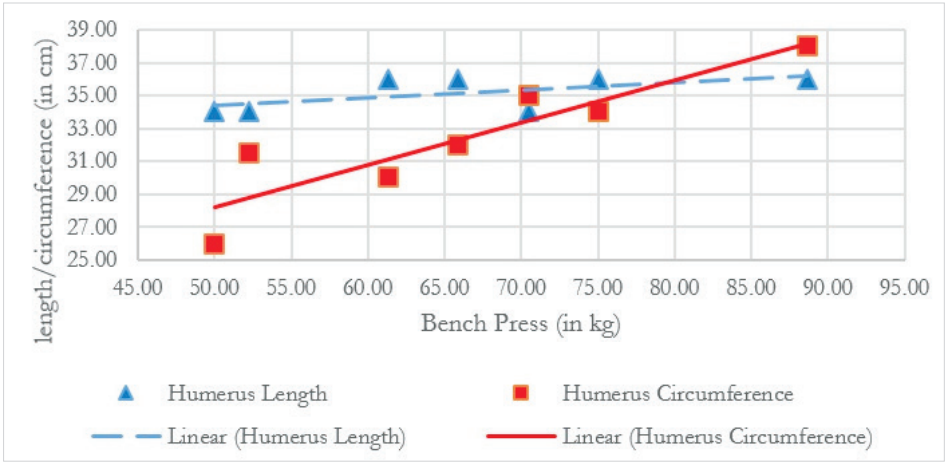

Figure 3. Bench press vs. humerus length/circumference in males.

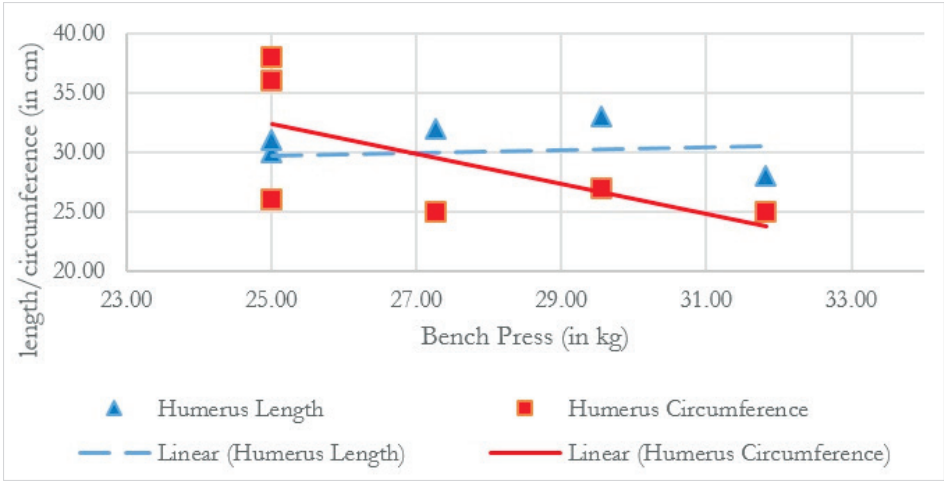

Figure 4. Bench press vs. humerus length/circumference in females.

Discussion

For males, limb circumference was strongly correlated with higher five repetition maximums. However, this relationship was not seen with limb length. This seems to demonstrate overall body size is more indicative of maximal muscle strength than height/limb length. Males also saw a strong relationship between height and weight with maximal muscle strength. This further reinforces body type as a strong predictor of muscle strength. It does not matter how tall an individual is or how long their limbs are, but the overall build of the body does matter. In both populations, the bench press results and leg press results were correlated. It is logical that balanced upper and lower body strength would be comparable in each individual.

Female results did not allow for a similar conclusion to be drawn. However, the small sample size and limited variance in the female sample could have played a role in the lack of similar results in the female population. The range was very small height-wise for the females in the population with just a four-inch difference. The small sample size was the biggest limiting factor in the study. The data from the active versus sedentary population in this study was much too small when accounting for gender that no reasonable conclusion could be drawn from the data. A much larger sample size is needed to accurately predict if activity level plays a role in accounting for overall strength. The active group of the females only had two subjects so it would be highly illogical to try to draw conclusions based off the results. However, because significant correlations occurred with males between limb circumference and overall strength, conclusions for the population could be drawn. Due to the small sample size, generalizations about the general population cannot be drawn for females.

Current research material focuses on anthropometric data of powerlifters, while this study focused on the natural strength of individuals. Future research should be done with ample sample sizes and a considerable variance among the sample size since promising results were not seen with such a small size. The experience level of the population could also be considered and examined to see if similar results occur with trained individuals outside of powerlifters, such as athletes from different sports. Another variable that could be manipulated in this area is age. This study looked at college-aged individuals. Different results could be seen in a youth population before puberty occurs, or in older adults as well. Practically, results from these studies could be used to predict success in lifting for individuals. Also, results could be used to personalize a strength prescription program for a client based off the client's body type in order to maximize the goals of the individual.

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Humanities and Public Affairs

Zachary J.M. Beck

The Tongue is a Fire: Blasphemy and the Virgin Mary in the Spanish and Mexican Inquisitions

Abstract

This research argument analyzes the relationship between blasphemy and the Spanish and Mexican Inquisitions in the sixteenth through eighteenth centuries. By investigating the crime of blasphemy as defined by the Inquisition in Spain and Spanish New World colonial possessions, this analysis considers the goals and purposes of the Inquisitorial tribunals that persecuted those who committed these sins of the tongue. Of particular note are those Inquisitorial cases involving blasphemy against the Virgin Mary and the ways in which various blasphemies offended the ideals of social and sexual conduct held by the Roman Catholic Church. Through a careful analysis of primary source transcripts, the author argues that while the Spanish and Mexican Inquisitions were related in their goal of punishing and eliminating blasphemy, their purposes for doing so were fundamentally different. In Spain, eliminating blasphemy was tied to religious morality and the ultimate goal of forming a pure, Catholic Spain. In Mexico, while religious morality and propagating Catholic doctrine were doubtlessly important, the persecution of blasphemy in the New World was intimately tied with larger problems of social control, especially those relating to gender, sexuality, and sexual conduct.

Introduction

In early 1662, a group of desperate women begged for alms outside a gambling house in Mexico City. Ana Muñoz Vera, a poor, thirty-eight-year-old in the group, asked one of the men, Jaime Viadel, for money. Viadel proceeded to throw Vera a coin, but another beggar quickly snatched it. At this point, a third woman pleaded with Viadel to also provide her with a coin, "for the love of the Virgin."[1] Infuriated and irritated, Viadel reportedly told the woman, "Get away from me, whore, and go fuck yourself with the Virgin's prick!"[2]

Offended and scandalized, two of the beggars denounced Viadel to the Mexican Inquisition for his blasphemous oath. The Inquisition tried to sentence Viadel for his crime, demanding he hear a mass while gagged with a rope around his neck and holding a green candle and that he abjure *de vehementi*.[3]

1. Javier Villa-Flores, *Dangerous Speech: A Social History of Blasphemy in Colonial Mexico* (Tucson: University of Arizona Press, 2006), 100.

2. Ibid.

3. For the particulars concerning the different types of abjurations demanded by the Spanish Inquisition, see John F. Chuchiak IV, ed. and trans., The Inquisition in New Spain, 1536-1820: A Documentary History (Baltimore: The Johns Hopkins University Press, 2012), 47-48. Concerning abjuration de vehementi, per Chuchiak, "Abjuration de vehementi was required of a penanced heretic when the inquisitors seriously suspected the defendant to be guilty

The Holy Office also insisted Viadel parade through town naked to the waist on a beast of burden while a crier proclaimed his offenses and, afterward, prescribed he receive two hundred lashes. Finally, the Mexican tribunal ordered him to serve as a galley slave for ten years and required he be instructed in the basics of Christian doctrine.[4] In blaspheming against the Virgin Mary, Viadel offended the sanctity of the Virgin herself and the sanctity of the Catholic Church and its teachings concerning the Mother of God. Viadel's case, however, entailed neither the first, nor the last, nor the worst blasphemy heard by the Inquisition.

The Catholic Church's Stance on Blasphemy

Blasphemy has had a long, problematic history in the Judeo-Christian tradition. The writings of what became both the Hebrew Bible and the New Testament gave great attention to the matter, due in large part to the seriousness with which ancient Jews viewed the sin.[5] The Book of Leviticus, for example, contains the following passage concerning blasphemy and its consequences:

> The LORD said to Moses, saying: Take the blasphemer outside the camp; and let all who were within hearing lay their hands on him, and let the whole congregation stone him. And speak to the people of Israel saying: Anyone who curses God shall bear the sin. One who blasphemes the name of the LORD shall be put to death; the whole congregation shall stone the blasphemer. Aliens as well as citizens, when they blaspheme the Name, shall be put to death.[6]

The Letter of James similarly notes the dangers of inappropriate speech and the power of the human tongue, proclaiming:

> How great a forest is set ablaze by a small fire! And the tongue is a fire. The tongue is placed among our members as a world of iniquity; it stains the whole body, sets on fire the cycle of nature, and is itself set on fire by hell. For every species of beast and bird, of reptile and sea creature, can be tamed and has been tamed by the human species, but no one can tame the tongue—a restless evil, full of deadly poison.[7]

of heresy; however, despite the evidence produced against him, he refused to confess."

4. Villa-Flores, 100.

5. Jeffrey B. Gibson, "The Function of the Charge of Blasphemy in Mark 14:64," in The Trial and Death of Jesus: Essays on the Passion Narrative in Mark, ed. Geert van Oyen and Tom Shepherd (Leuven: Peeters, 2006), 171, 174-75.

6. Leviticus 24:13-16 (New Revised Standard Version).

7. James 3:5b-8 (NRSV).

It thus followed that the Spanish Inquisition and, later on, the Mexican Inquisition, considered it essential to prosecute those who blasphemed. The need to promote religious orthodoxy—and, therefore, to increase the power of the Catholic Church in Spain and its New World colonies—propelled the institutions and their actions. From the inception of the Inquisition in Spain in 1478, the institution aimed primarily to eradicate formal religious heresy, those opinions and beliefs that did not follow the tenets of orthodox Christian faith and the Catholic Church's teachings. The Spanish inquisitors moved quickly, however, to expand their jurisdiction to include various other crimes, arguing these crimes might also hide heretical intention. Chief among these were the rejection of God's laws and commandments and the doctrines of the Catholic Church.[8] In this way, blasphemy became a crime monitored, tried, and punished by the Spanish Inquisition and, subsequently, the Mexican Inquisition.

Indeed, blasphemy became one of the most recurrent crimes proceeded against by the inquisitorial institutions of Spain and Mexico.[9] Individuals frequently uttered blasphemous words against God or the saints, but it is most interesting to consider blasphemy against the Virgin Mary, who occupied a special, albeit controversial, place in the dogma of the Catholic Church and, perhaps because of this, became a particularly popular subject of blasphemy.

But why did the Spanish and Mexican Inquisitions feel compelled to prosecute blasphemers in the first place? Why did blasphemers choose to degrade the Virgin Mary? How did blasphemy of the Virgin Mary relate to the Inquisition, the Catholic Church, and society at large? Such questions prove crucially important and must be analyzed to fully understand the relationship between the Inquisitions of Spain and Mexico and the crime of blasphemy. The Spanish and Mexican Inquisitions' pursuits and punishments of blasphemy, especially blasphemy relating to the Virgin Mary, depended upon the larger social contexts relating specifically to each area. In Spain, the necessity of controlling blasphemy was rooted in the deeper goal of ensuring religious morality in the Spanish population and transforming Spain into a purely Catholic nation. In Mexico, the prosecution of blasphemy related to broader problems of social control and issues of sexual morality and gender, matters that tied intimately into the dogmas of the Catholic Church and the type of society that the Inquisition sought to establish in the New World.

8. John F. Chuchiak IV, ed. and trans., *The Inquisition in New Spain, 1536-1820: A Documentary History* (Baltimore: The Johns Hopkins University Press, 2012), 2-5.

9. Henry Kamen, *The Spanish Inquisition: A Historical Revision* (New Haven: Yale University Press, 1997), 260-62; see also Javier Villa-Flores, *Dangerous Speech: A Social History of Blasphemy in Colonial Mexico* (Tucson: University of Arizona Press, 2006), 6

Defining Blasphemy

When discussing a term as variously identified and used as blasphemy, one must look first at what the term meant and encompassed and, additionally, how views of blasphemy during the era of the Inquisition differed. Varying yet fundamentally interconnected definitions of the term existed for the Inquisition. Specialist on the Inquisition Henry Kamen described blasphemy simply as "disrespect to sacred things" and claimed inquisitorial tribunals "gave the term a very broad definition."[10] Historian Toby Green argued blasphemy "tended to come into one of three categories": a general disparagement of the Church and its institutions, an expression of overt skepticism relating to the existence of God, and an explosive type of blasphemy concerning sexual deviance.[11] In his study of blasphemy in colonial Mexico, Javier Villa-Flores noted that "theologians and moralists generally defined blasphemy as a 'sin of the tongue'" and highlighted Medieval philosopher Saint Thomas Aquinas's definition of blasphemy as "an insult against God, disparaging his divine goodness" that "took three forms: attributing to God any characteristic that does not conform to his nature . . .; denying to God attributes that belong to him only . . .; or ascribing to a creature qualities that conformed only to God."[12] Villa-Flores proceeded:

> Insults and verbal assaults—such as swearing by Christ's limbs, abjuring or renouncing God, or giving oneself to the devil—were also deemed blasphemous not because of the actual meaning of these expressions but on account of the irreverent way in which God was addressed by his creatures. Similarly blasphemous were expressions that attacked the Virgin, the saints, or sacred things . . . for they rebounded to God as their creator and giver of sanctity.[13]

For the Spanish and Mexican Inquisitions, however, the difficulty surrounding blasphemy related to uncertainties between instances in which the inquisitors needed to prosecute and punish the crime as heretical and detrimental to the Catholic faith and instances in which the inquisitors could dismiss the blasphemous happenstance as a mere slip-of-the-tongue, an accident inherent in human imperfection. The distinction between the superficial blasphemies originating in moments of anger, emotion, or poor habits and the ill-conceived heretical propositions that called into question the virginity of Mary, the

10. Kamen, 261.
11. Toby Green, *Inquisition: The Reign of Terror* (New York: Thomas Dunne Books, 2009), 223.
12. Villa-Flores, 9.
13. Ibid.

divinity of Jesus Christ, or the intercession of the heavenly saints demanded much consideration.[14]

Ultimately, the Inquisition established two categories of blasphemy: simple blasphemy and heretical blasphemy. Simple, non-heretical blasphemy included issues of emotional exclamations or insults against God and the Virgin Mary, while heretical blasphemy explicitly involved a denial of the tenets of the Catholic faith or of the existence of God, the Virgin Mary, or the saints.[15] Indeed, blasphemous remarks that did not attack or call into question any article of the Catholic faith had no bearing on the Inquisition and thus drew no attention nor garnered any response from the institution.[16] For those blasphemous remarks that contained heretical ideas, however, there existed no clear distinction between the heresy and the blasphemy, and each aspect included and involved the other.[17] Among the worst of the heretically blasphemous remarks were those that targeted the Virgin Mary.[18]

The Scriptural Basis for Catholic Theology and the Crime of Blasphemy

Before investigating these blasphemies—and as necessary to understanding their implications—one must examine the beliefs of the Catholic Church and the dogmas that defined the Spanish and Mexican Inquisitions. Such an examination provides the appropriate context for analyzing blasphemy.

The sacred Scriptures of the Bible provided the fundamental basis for the doctrines and dogmas that concerned Mary and her position in the Catholic faith—and not merely the writings of the New Testament, in which Mary physically appears as the Virgin Mother, but in the Old Testament, as well, in which the Catholic Church saw Mary prefigured and anticipated. Perhaps most famous of the Old Testament prophecies that the Church interpreted as relating to Mary occurred in chapter seven of the Book of Isaiah. In this prophecy, Isaiah declared to the land of Judah that "the Lord himself will give you this sign: the virgin shall be with child, and bear a son, and shall name him Immanuel," a name meaning "God is with us."[19] Following the interpretation of the Gospel of Matthew, the Church believed this passage alluded directly

14. Francisco Bethencourt, *The Inquisition: A Global History, 1478-1834* (Cambridge: Cambridge University Press, 2009), 51.

15. Chuchiak, 205

16. Martin Austin Nesvig, *Ideology and Inquisition: The World of the Censors in Early Mexico* (New Haven: Yale University Press, 2009), 86-87.

17. Richard E. Greenleaf, *Zumárraga and the Mexican Inquisition, 1536-1543* (Washington, DC: Academy of American Franciscan History, 1961), 101.

18. Nesvig, 87.

19. Isaiah 7:14; Matthew 1:23 (New American Bible).

to the birth of Christ to the Virgin Mary. Both the Gospel of Matthew and the Gospel of Luke placed great emphasis on the virginity of Mary. Matthew declared Mary conceived Jesus Christ strictly through the Holy Spirit.[20] Luke further delineated the pure virginity of Mary. According to Luke, after Gabriel announced to Mary she would conceive and bear a son, Mary questioned, "How can this be, since I have no relations with a man?", to which the angel responded that "the holy Spirit will come upon you and the power of the Most High will overshadow you. Therefore the child to be born will be called holy, the Son of God."[21]

Building upon this idea, the early Catholic Church established a doctrinal belief in the perpetual virginity of Mary, a claim that proved controversial not only at the time of its establishment but also continued throughout the centuries to spark silent and spoken controversy and disbelief even among contemporary practitioners of the Catholic faith. The expansion of the doctrine of Mary's virginity began at the Council of Chalcedon in 451.[22] The Council commenced with the reading of a letter from Pope Leo to a bishop of Constantinople. In this letter, Pope Leo followed the Gospels in declaring Jesus Christ as "born of the holy Spirit and the Virgin Mary" but then propounded Mary's virginity "was as untouched in giving him birth as it was in conceiving him."[23] Though this notion did not necessarily establish the perpetual virginity of Mary, it nonetheless signaled a step in that direction, and it proved pivotal as time progressed.

Just over a century later, at the Second Council of Constantinople in 553, the perpetual virginity of Mary was fully established as indisputable doctrine of the Catholic Church.[24] The Second Council of Constantinople employed the term "ever-virgin Mary" in its discussions, declaring her the purely virgin mother of God. Most notably, the Council's sixth anathema against the "Three Chapters" stated:

> If anyone declares that it can only be inexactly and not truly said that the glorious ever-virgin Mary is the mother of God, or says that she is so only in some relative way, considering that she bore a mere man and that God the Word was not made into human flesh in her, holding rather that the nativity of a man from her was referred, as they say, to God the Word as he was with the man who came into being; . . . or if

20. Matthew 1:18-20 (NAB).

21. Luke 1:31-35 (NAB).

22. Norman P. Tanner, ed., *Nicaea I to Lateran V*, vol. 1 of *Decrees of the Ecumenical Councils* (London: Sheed & Ward, 1990), 75.

23. Ibid., 77

24. Ibid., 105.

> anyone says that she is the mother of a man or the Christ-bearer, that is, the mother of Christ, suggesting that Christ is not God; and does not formally confess that she is properly and truly the mother of God . . .: let that person be anathema.[25]

In this manner, by the middle of the sixth century, the Catholic Church included in its foundational beliefs the doctrine of the perpetual virginity of the Virgin Mary. The Church again confirmed this doctrine at the Fourth Lateran Council in 1215,[26] and at the 1546 Fifth Session of the Council of Trent, the Church added the Immaculate Conception to its Marian doctrines, proclaiming in regards to its decree of humanity's inescapable original sin, "It is not [the Council's] intention to include [in this decree] . . . the blessed and immaculate Virgin Mary, the mother of God."[27]

Difficulties Among the Laity with the Catholic Concepts of Mary's Virginity

The implications of the aforementioned Church doctrines concerning the Virgin Mary—and the powerful interpretations resulting from them—became highly influential. By the Church's self-proclamation, being Catholic involved accepting the Virgin Mary as the stainless, pure vessel through which God became man and dwelt among the human race. Being a Catholic Christian meant honoring the sanctity of Mary and following her example as the handmaid of the Lord, an example of a holy life lived in accordance with the will of God. Being a Catholic Christian demanded adherence to the teachings and dogmas of the Church, guided by the Mother of the Church—Mary herself.

The exaltation of Mary, however, proved difficult for many practitioners of the Catholic faith. The Church's steadfast belief in Christ's virgin birth as well as Mary's perpetual virginity and sinless life caused both silent and spoken disbelief and controversy, even among Spanish Catholics. For lay Spanish Catholics, the Marian dogmas of the Church stretched believability to its greatest lengths, contributing to skeptical and blasphemous statements against the Virgin Mary and to the Inquisition's desire to crush anti-orthodox irreverence.

In order to understand the desires of the Spanish Inquisition, one must investigate the historical context that gave rise to the institution and the social and religious environment in which it operated. The Spanish Inquisition, known also as the Holy Office of the Inquisition, existed as one tribunal in a

25. Tanner, ed., 116.

26. Ibid., 230.

27. H.J. Schroeder, trans., *The Canons and Decrees of the Council of Trent* (Rockford, IL: Tan Books and Publishers, 1978), 23.

long line of ecclesiastical tribunals created by the papacy to eliminate heresy throughout Christendom. In Spain, however, the Spanish Crown directly controlled the Inquisition. Reigning Spanish monarchs Ferdinand and Isabella secured control of the institution, claiming that suppressing the spread of heresy, especially among the growing population of recently-converted New Christians, required direct influence from the King and Queen.[28]

The Inquisition's Quest for Doctrinal Purity and the Attacks Against Heretical Blasphemy

Inherent, then, in the Spanish Inquisition—and underscoring its eagerness to extirpate heresy—dwelled its ultimate desire to create a purely Catholic Spanish nation as divinely ordained by God. Indeed, upon the edict of expulsion against the Jews issued by King Ferdinand in 1492, Queen Isabella claimed that "the Lord has put this thing into the heart of the king."[29] The Divine Will, according to Isabella, guided the actions and decisions of Ferdinand, and the monarchy, in turn, demanded orthodoxy.[30] The Inquisition, therefore, pursued and prosecuted those acting in religiously unsound ways because the institution deemed it necessary to do so in order to conform them to the spiritual laws of the Church and, in this way, to make Spain and its Catholic people a holy nation for God's own possession. How could this become reality, though, with the presence of blasphemy against God and the Virgin Mary? The Inquisition deemed the coexistence of blasphemy and pure Catholicism impossible, and thus the Holy Office needed to punish blasphemers in order to lead them back to the Catholic fold.

Fundamentally, the problem of blasphemy in Spain had two distinct sides, both of which conflicted with the ultimate aims of the Inquisition. First, blasphemy occurred many times in conjunction with what the Church considered immoral behaviors, and second, it represented a clear sign of doctrinally unsound thought and, thus, irreligion.[31] In many instances, the first side of the issue gave way to the second, most especially relating to gambling and blasphemy.

The 1545 trial of Diego de Almodovar of the village of Aboler presented the typical relationship between gambling and blasphemy. In his self-denunciation, Diego de Almodovar told the Spanish Inquisition "that within the

28. Richard L. Kagan and Abigail Dyer, ed. and trans., *Inquisitorial Inquiries: Brief Lives of Secret Jews and Other Heretics*, 2nd ed. (Baltimore: The Johns Hopkins University Press, 2011), 11-12.

29. Kamen, 20.

30. France V. Scholes, "An Overview of the Colonial Church," in *The Roman Catholic Church in Colonial Latin America*, ed. Richard E. Greenleaf (Knopf: New York, 1971), 19.

31. Sara T. Nalle, *God in La Mancha: Religious Reform and the People of Cuenca, 1500-1650* (Baltimore: The Johns Hopkins University Press, 1992), 62.

last twenty years, a little more or less, I acquired a vice, namely gambling." Almodovar proceeded to explain, "Sometimes when I practiced the said vice, I said with anger and passion . . . 'I don't believe in God' and 'I deny God.'"[32] Almodovar's testimony followed the typical gambling-blasphemy template, in which God failed to help a gambler in his goals and therefore became the target of the gambler's ire. Nonetheless, the Inquisition punished Almodovar, declaring that "he shall hear the major mass that is said in the church of the village of Alcalá, from the point it begins until it ends, standing upright before the steps of the major altar . . . he shall be barefoot and barelegged, and hold a lit wax candle . . . he shall pray five *Ave Marias* and four *Pater Nosters*."[33]

This case illustrated the basic methods the Inquisition utilized in handling cases of blasphemies related to gambling or other public sins. Many of these cases involved blasphemous statements that individuals exclaimed, as stated by Diego de Almodovar, out of "anger and passion."[34] Hence, while the Inquisition considered such statements as worthy of punishment, the statements themselves did not suggest the level of intentional heretical thought evident in other cases. These cases of simple blasphemy seriously threatened neither the foundation of Spanish Catholicism nor the fabric of the Spanish nation. However, cases involving heretical propositions against the Virgin Mary, such as those evidenced in the case of Juan Bautista de Cubas, did.

Friar Juan Bautista de Cubas lived as a Jeronimite monk at the Monastery of San Lorenzo el Real.[35] As a friar, Juan Bautista de Cubas's possessed a noteworthy and powerful position within the Church, and therefore, he had the ability to influence his fellow monks. Because of this, the Spanish Inquisition saw his heretical blasphemies and ideas as directly dangerous to the authority and power structure of the Church, for if a friar held heretical ideas, his potential to contaminate others with false dogma could greatly and swiftly undermine the pure beliefs of Catholic doctrine. It fell to the Spanish Inquisition to prevent this from happening.

Friar Juan Bautista's heretically blasphemous propositions took aim directly at the Virgin Mary and the Catholic Church's beliefs pertaining to her. First, he "affirmed that anyone who said that the Virgin Mary's body had not yet been assumed into heaven would not be a heretic or a disseminator of errors detrimental to the Catholic faith, since church councils had not decreed it."[36]

32. "Trial of Diego de Almodovar, Penanced for Blasphemy, 1545," in *The Spanish Inquisition, 1478-1614: An Anthology of Sources*, ed. and trans. by Lu Ann Homza (Indianapolis: Hackett Publishing, 2006), 166.

33. "Trial of Diego de Almodovar," 167.

34. Ibid.

35. Lu Ann Homza, ed. and trans., *The Spanish Inquisition, 1478-1614: An Anthology of Sources* (Indianapolis: Hackett Publishing, 2006), 248.

36. "Scandalous Propositions. Friar Juan Bautista de Cubas, Monastery of San Lorenzo el Real. Penanced, 1581," in *The Spanish Inquisition, 1478-1614: An Anthology of Sources*, ed. and trans. by Lu Ann Homza (Indianapolis: Hackett Publishing, 2006), 249.

Though Juan Bautista correctly claimed that no official Catholic Church council had provided a decree on the Assumption of the Blessed Virgin Mary,[37] the doctrine of the Assumption had nonetheless acquired the papal endorsement by 863.[38] As such, by the time of the friar's comments 700 years later, within the Church and the sound ideas of Catholic doctrine, there could be no question concerning the validity of the Assumption.[39]

Beyond this, Juan Bautista de Cubas blasphemed against the Virgin Mary by personally attacking the Church doctrine of the miraculous Immaculate Conception. As the friar stated:

> I said that I wanted to endorse the opinion that says Our Lady was conceived in original sin, because scriptural authorities attest this, and not the reverse. I said that I wanted to hold this opinion until the Church determined otherwise. If Our Lady was conceived in original sin, they do her no honor in saying that she was not, attributing to her what she does not have.[40]

Juan Bautista's argument betrayed many points of false orthodoxy. Surely the inquisitors wondered about the scriptural authorities to which he referred, for no direct address of the Immaculate Conception occurred in the Bible. Perhaps the friar had received misinformation upon this point, as he clearly had in his declaration that he sought to hold his view that the Virgin had been conceived in sin "until the Church determined otherwise."[41] As previously mentioned, the Church declared the Immaculate Conception at the Fifth Session of the Council of Trent in 1546, some thirty-plus years prior to Juan Bautista's statements.[42]

Despite his apparent lack of awareness concerning the decrees of the Church, the Spanish Inquisition deemed it necessary to punish Juan Bautista to protect itself, along with the Catholic faith it served, and to right the misguided views of the friar. As such, Juan Bautista received a harsh sentence: "The inquisitors imposed, as penance, that he fast for nine Fridays. . . . The inquisitors ordered him to pray seven psalms for all nine Fridays, with the prayer that the Church says on the day of the Assumption. . . . And he cannot be promoted to other

37. According to Catholic Church doctrine, the Assumption of the Virgin Mary declared that upon Mary's death, God raised her from the dead and assumed her —body and soul — into heaven. See Marina Warner, *All Alone of Her Sex: The Myth and Cult of the Virgin Mary* (New York: Knopf, 1976), 81-102.

38. Homza, 248.

39. Ibid.

40. "Scandalous Propositions," 249.

41. Ibid.

42. Schroeder, 23.

ranks without permission from the illustrious Inquisitor-General."[43]

While the punishment in the two religious penances fit the general template for the friar's crime, the Inquisition revealed its underlying fears and motivations in handing down the third punishment, which prevented the friar's advancement to higher ranks within the Church. By voicing his heretically blasphemous ideas, Juan Bautista became a threat to the Church, and the friar's crime demanded that the Inquisition strike at his position within the Church and place checks on his realm of influence. Had it not done so, the Inquisition would have blatantly failed itself and its fundamental purposes. The Inquisition recognized that those with more authority, power, and status necessitated forceful reprehension and correction, for the false ideas of but a single powerful person could become a matter of utmost danger.

The Relationship between *Alumbradismo* and Heretical Blasphemy

The case of Juan Bautista illustrates a close connection between heretical, blasphemous statements of individuals and the necessity of the Inquisition to protect the purity of the Catholic faith. The Inquisition in Spain, however, did not merely treat individual heretically blasphemous ideas in this way, but it also treated the shared heresies of the *alumbrados* in a similar manner.

Lu Ann Homza described *alumbradismo* as "an amorphous spiritual movement that became one of the Inquisition's key targets in the 1520s."[44] The *alumbrados*, those who adhered to the precepts of this movement, unsettled the Church by "believ[ing] they possessed an illuminated spirituality because they had abandoned themselves to the love of God" and "reject[ing] the external rituals of Catholicism, such as . . . praying to saints as intercessors."[45] In an Inquisition edict on the *alumbrados*, the *alumbrados* attacked the Virgin Mary and the Marian doctrines of the Catholic faith. The Spanish inquisitors, the great defenders of Spanish Catholicism, struck back.

The *alumbrados*' "erroneous, blasphemous, and heretical" beliefs threatened the Spanish Inquisition specifically because the *alumbrados*' propositions, to use the words of the inquisitors, "separate[d] men from the devout and holy customs of the Holy Mother Church."[46] The *alumbrados* called it wicked "to adorn the statue of our Lady, the Virgin Mary, and take her in a procession

43. Ibid., 251.

44. Homza, 80.

45. Ibid.

46. "1525 Inquisition Edict on the Alumbrados," in *The Spanish Inquisition, 1478-1614: An Anthology of Sources* ed. and trans. by Lu Ann Homza (Indianapolis: Hackett Publishing, 2006), 86.

through the street" and referred to the statue of the Virgin as an idol.[47] Similarly, the *alumbrados* said "that people were not healed by venerating the statues of our Lord and our Lady, which were simply sticks," and "they laughed when men did revere them, saying that the statues, being sticks, took no notice of them."[48] Finally, they did not venerate or possess any statue of Mary and declared one could "recall the Virgin Mary by looking at a woman."[49]

Such statements naturally propelled the Spanish inquisitors into a state of frenzy. They declared these propositions against the Virgin Mary as wrong and heretical, as crazy and scandalous, as false and erroneous. They described the blasphemous *alumbrados* as rash and condemned them for "err[ing] against the praiseworthy customs of the Church" pertaining to the Virgin.[50] Ultimately, the inquisitors made an impassioned plea to their Catholic brethren, begging them to avoid the false beliefs of the *alumbrados* and to adhere steadfastly to "the Catholic things that you must believe in order to save your souls, and the things you must avoid in order not to lose the glory for which you were created."[51] Along with this, however, the inquisitors issued a demand and a promise:

> At present, we order you to withdraw from all the said errors and novelties [of the *alumbrados*], not to believe or uphold them, and not to be swayed into them by other people, whether publicly or secretly, in your houses or outside of them, alone or assembled. [If you] do the opposite . . . we will proceed against each and every one of you . . . just as we proceed against heretics and transgressors of things that are divinely ordained and taught by our Holy Mother Church.[52]

In each of these aforementioned instances of heretically blasphemous propositions and notions, the Spanish Inquisition intervened because the precepts, teachings, and doctrines of Spanish Catholicism were under siege. According to Spanish historical specialist Sara T. Nalle, the Inquisition's campaign against blasphemy in Spain related to a wider church effort to control the foul-mouthed abuse of God.[53] True as this is, the Spanish Inquisition's efforts certainly included additional motivations. As the previously analyzed documents indicate, the Inquisition sought not only to punish and eradicate the abuse of God but also to punish and eradicate the abuse of the Catholic

47. Ibid.
48. "1525 Inquisition Edict on *Alumbrados*," 86.
49. Ibid.
50. Ibid.
51. Ibid., 91.
52. Ibid., 91–92.
53. Nalle, 62.

faith, particularly concerning its Marian doctrines. To deny or blasphemously contradict the perpetual virginity of Mary, her Immaculate Conception, or her Assumption inherently included denying the teachings and dogmas of the Catholic Church and suggested the fallibility of the Church Fathers, the Church Councils, and the role of the institution of the Inquisition itself.

The Spanish Inquisition believed that no decent Catholic of sound faith would fall victim to morally or religiously depraved thoughts and actions.[54] The heresy of blasphemy thus signified both a moral and religious problem, and those who blasphemed against the Virgin Mary represented the height of moral depravity and irreligiosity. As the unblemished, exalted Mother of God, the Virgin Mary existed as a symbol for Spanish Catholics of a life lived in servitude of God and in communion with the Divine Will. The Catholic Church devoted itself to Mary because of what it perceived as divine mandate. For one to question, deny, or spread ideas contrary to the teachings of the Catholic Church highlighted one's misguided, potentially contaminating religious beliefs.

The Spanish Inquisition could not allow such things to go unnoticed, and thus it worked to combat heretical blasphemy, particularly blasphemy against the Virgin Mary, to ensure the uniform belief of all Spanish Catholics. The Inquisition in Spain sought to protect the Spanish Catholic faith and, in doing so, to protect and care for the Spanish Catholic flock. In the flourishing of the Catholic Church among all its members, the Spanish Inquisition desired to achieve its ultimate aim of a purely unified Catholic nation.

Blasphemy and the Mexican Inquisition

The Mexican Inquisition in New Spain, however, differed in some ways from the Inquisition on the European continent. As such, the efforts of the Mexican Inquisition manifested in a distinct manner and for distinct ends. The Inquisition in New Spain concerned itself with the propagation and preservation of the Spanish Catholic faith and acted to ensure the morality of the Mexican population, but many problems that the Mexican Inquisition faced related to deeper issues of social control, including matters of slavery, gender roles, and sexual morality. Accordingly, the crimes of blasphemy in New Spain—and the Inquisition's prosecution of these crimes—progressed differently from cases on the European continent.

The Inquisition in New Spain developed in three periods. Historians refer to the first period as the era of the early monastic inquisitions. This period began in 1522, and the local leaders of the monastic religious orders dominated

54. Ibid., 64.

the proceedings of these inquisitions. The second period, which commenced in 1536, saw the brief transcendence of the episcopal inquisition, in which the bishops and archbishops of Mexico filled positions as inquisitors and prosecuted various cases of heresy. The third period of the Inquisition witnessed the official birth of the Holy Office of the Inquisition in New Spain in 1571.[55]

Problems of blasphemy in New Spain occurred immediately after the Spanish Conquest. As early as 1520, Hernán Cortés initiated a movement in the Spanish colony to punish blasphemers, warning that Spain's legal punishments prescribed for blasphemers would be enforced.[56] Following suit, the early monastic inquisitions involved itself in the crime from the beginning of its existence. Of the 55 cases tried by Fray Domingo de Betanzos and other Dominican inquisitors between 1526 and 1536, 22 were cases of blasphemy, a number almost double the second most common type of case, which involved idolatry and sacrifices.[57]

Blasphemy of the Virgin Mary rose to prominence from the beginning, as well. Conquistador Rodrigo Rengel became one of the first blasphemers of the Virgin in Spain's New World colonies. Rengel doubted the virginity of Mary and stated his opinion that Joseph "had taken carnal access to Mary" and therefore assisted in the conception of Jesus Christ.[58] Following this train of thought, Rengel referred to the Virgin as a whore,[59] highlighting early instances of blasphemous remarks that became some of the most common blasphemies in New Spain.

The crime of blasphemy showed no signs of slowing as it entered the era of the episcopal inquisition. Upon becoming the first bishop of Mexico, Fray Juan de Zumárraga instigated a systemized episcopal inquisition that prosecuted various cases of heresy. Unsurprisingly, blasphemy became the crime Zumárraga prosecuted most. In a ten-year-period beginning in 1536, Zumárraga and his episcopal inquisition tried 156 cases, 56 of which were cases of blasphemy. Cases of superstitions, the second most common type of case tried by the bishop, occurred only 23 times.[60] Blasphemy continued to reign supreme.

Specialist in Mexican colonial history Martin Nesvig posited that Fray Zumárraga tried and punished such a great number of cases of blasphemy because he desired to ensure the social morality of the early Spanish settlers of New Spain.[61] This is certainly true, but it appears as though the episcopal

55. Chuchiak, 8-12.

56. Richard E. Greenleaf, *The Mexican Inquisition of the Sixteenth Century* (Albuquerque: University of New Mexico Press, 1969), 9.

57. Chuchiak, 9.

58. Greenleaf, 102.

59. Ibid.

60. Chuciak, 10.

61. Nesvig, 107.

inquisition concerned itself with more than simple social morality. The bishop could not have been blind to the deeper problems that existed in some of these cases of blasphemy. The trial of Juan de Villate, which involved blasphemy and the Virgin Mary, illustrated the fundamental tensions of gender and marriage fomenting beneath the surface of blasphemy in colonial New Spain.

The trial and proceedings against the tailor Juan de Villate occurred in Mexico City in 1539, during the heart of Zumárraga's crusade against blasphemy. In the testimony against Villate, Zumárraga heard from Lope Gallego, a former worker in the house of the tailor, the way in which Villate rebuked Juana Gómez, his wife, for praying the Rosary before an image of the Virgin Mary. Gallego testified that when Villate found Gómez praying to Mary, the tailor ripped the Rosary beads from Gómez's hand and told her, "You should not pray so much to God; it is better to pray to the Devil!"[62] Again, according to Gallego, in another instance in which Villate saw Gómez beseeching the Virgin, Villate "had fought with her and taken from her the beads that she was praying with and he slapped her in the face several times and told her, 'I swear to God if I find you praying again with those beads I will throw them into a well and burn your hands.'"[63]

While Villate denied having told his wife to pray to the Devil instead of God, he nonetheless stated that upon coming home to eat on various instances, he found that his food had not yet been made and that instead of preparing his meal, he saw his wife praying with her Rosary beads. Under these circumstances, Villate admitted to telling his wife, "You never take out those beads until you see me coming home to eat . . . To the Hell with your damn beads because those beads don't commend you to God, but rather to the Devil!"[64]

Thus, Villate claimed that his wife provoked his blasphemous statements by failing to fulfill what he doubtlessly saw as her appropriate wifely duties. While Villate did not blaspheme directly against the Virgin Mary, her role in this case of blasphemy proved nonetheless intriguing. Spanish Catholic prayer to the Virgin often sought her protection from dangerous and frightening situations.[65] Interestingly, in her testimony, Juana Gómez identified Villate as an unfaithful husband who frequently committed adultery with a native woman and gave Gómez a bad life overall. Gómez further admitted that "she prays when [Villate] wishes to come and lay with her."[66] The actions and testimonies

62. "Inquisition Trial and Proceedings against the Tailor Juan de Villate for Blasphemy and Heretical Propositions," in *The Inquisition in New Spain, 1536-1820*, ed. and trans. by John F. Chuchiak IV, (Baltimore: The Johns Hopkins University Press, 2012), 210.

63. Ibid.

64. "Inquisition Trial and Proceedings," 212.

65. John Frederick Schwaller, *The History of the Catholic Church in Latin America: From Conquest to Revolution and Beyond* (New York: New York University Press, 2011), 33.

66. "Inquisition Trial and Proceedings," 211.

of both Villate and Gómez suggested a marital rift and a problem of sexual and gender roles. Villate's blasphemy entailed more than the simple problem of a verbal outburst.

The Blasphemy-Slavery Connection

Further considering blasphemy in New Spain and its relationship to broader societal and cultural troubles, various instances of blasphemy in connection with slavery became problematic for the Mexican Inquisition. A 1710 Inquisition document contains investigations and denunciations against a *mulatta* slave named Pascuala for her crimes of blasphemy.[67] Pascuala's case highlighted many factors common in slave blasphemy.

In the denunciations against Pascuala, the Mexican Inquisition heard testimony from Francisco de la Cruz that "he heard Pascuala . . . blaspheme. After her other female companions went into the fields to work . . . [Pascuala] exclaimed that she renounced the Holy Virgin and her precious son."[68] Similarly, Juan de Dios told the inquisitors that "while being in the Mill house, at about around eight o'clock at night, he heard that when the Overseer threatened her, Pascuala . . . said that 'Even if the Devil will take me, I will renounce the Holy Virgin, and all her saints, even if they whip me.'"[69] Finally, Miguel Ramírez testified that "he heard it said that a mulatta slave named Pascuala had renounced the Holy Virgin and her precious son, and . . . that [he] knows that the said Pascuala on many occasions while . . . in the fields has uttered curses and other vile and profane words out of desperation."[70]

In each of these testimonies, Pascuala's blasphemous claims and oaths related to harsh working conditions, threats, and the desperate situation of Pascuala's plight as a slave. In this way, Pascuala's crime proved typical as a case of slave blasphemy. Slave women became "particularly vulnerable to charges of renouncing God, usually during the course of . . . abuse and punishment, and sometimes in a deliberate bid to escape tyrannical owners."[71] Further, slave blasphemy tended to occur during bitter physical work and when slaves received punishment or the threat of punishment.[72] As such, "blasphemy

67. "Inquisition Testimony against Pascuala, a Mulatta Slave on the Sugar Plantation of Tlacomulco in the Region of Cuernavaca, for the Crime of Blasphemy," in *The Inquisition in New Spain, 1536-1820*, ed. and trans. by John F. Chuchiak IV, (Baltimore: The Johns Hopkins University Press, 2012), 214-17.

68. "Inquisition Testimony against Pascuala," 215-16.

69. Ibid., 216.

70. Ibid., 217.

71. Jacqueline Holler. "The Holy Office of the Inquisition and Women," in *Religion and Society in Latin America: Interpretive Essays from Conquest to Present*, ed. Lee M. Penyak and Walter J. Petry (Maryknoll, NY: Orbis Books, 2009), 126.

72. Kathryn Joy McKnight, "Blasphemy as Resistance: An African Slave Woman before the Mexican Inquisition," in *Women and the Inquisition: Spain and the New World*, ed. Mary E. Giles (Baltimore: The Johns Hopkins University Press, 1999), 233.

revealed the very nature of the slave system constituting as it did the slaves' instinctive reaction to an unbearable situation."[73]

Blasphemy thus became the most frequent crime for which the Mexican Inquisition tried and prosecuted slaves,[74] and slave blasphemy trials illustrated the power struggle between the slave and societal forces and the relationships among slaves, slaveholders, and the church and state, as represented by the Mexican tribunal.[75] The Mexican Inquisition held jurisdiction over slave blasphemy, and only the Inquisition claimed the power to absolve the blasphemer.[76]

As illustrated in the case of Pascuala, however, while the crime of slave blasphemy and the utterances of various oaths did concern the Inquisition and its religious authority, the crime had not only a religious aspect but also a broader societal aspect. Slave blasphemy entangled itself with the very culture of New Spain and complicated the question of where blasphemy ceased to be a matter of religion and more a defensive tool and mechanism used by slaves in order to express the harshness and inhumanity inherent in the institution of slavery itself. Slave blasphemy underscored expansive societal dilemmas concerning authority, insubordination, and the relationship between slaves and those who possessed power over them. Such issues provided the foundation for the crime of blasphemy.

Gender Roles, Sexual Morality, and Blasphemy

There also existed in New Spain, as only briefly touched upon above, a strong relationship between blasphemy, gender roles, and sexual morality—both for men and women. The cultural landscape in New Spain, however, dictated rather different roles for each gender, and through the expectations of gender convention in colonial New Spain, male and female blasphemy shaped itself in distinct ways for distinct purposes.[77]

Though women in New Spain rarely found themselves accused of blasphemy, colonial society nonetheless concerned itself with female blasphemy and the cosmic and social dangers engendered by a woman's unchained tongue.[78] According to the Judeo-Christian tradition, the incredibly malign potential of the female tongue stretched back to the very beginning of human existence: the sin of Eve in the Garden of Eden and its irreversible repercussions. The

73. McKnight, 233.

74. Holler, 126.

75. McKnight, 231.

76. Karoline P. Cook, "Navigating Identities: The Case of a Morisco Slave in Seventeenth-Century New Spain," *The Americas* 65, no. 1 (July 2008): 76, http://dx.doi.org/10.1353/tam.0.0030.

77. Villa-Flores, 105.

78. Ibid., 106.

well-controlled female tongue, therefore, became a defining aspect of the Spanish Catholic woman.[79]

This ideal of Christian womanhood, however, proved a difficult one to reach for certain women in New Spain. Yet such difficulties were perhaps unsurprising, given the colonial Mexican view of sinfulness as a natural characteristic of the female nature.[80] Nonetheless, in failing to curb their flaming tongues, women who blasphemed not only engaged in a sinful crime but also failed "to 'do gender' in the right way."[81] Female blasphemy fell short of the standards of Christian femininity, the model of which entailed the sinless submissiveness of the Virgin Mary.[82]

As a result, even when wives and mothers did not personally utter blasphemous oaths, women could find themselves ultimately responsible for the blasphemy of their husbands or children. By failing to fulfill their womanly duties or falling short in satisfying the feminine standard, women exasperated their husbands, causing the men to lose control of their own tongues and engage in blasphemous utterances.[83] The aforementioned case of the tailor Juan de Villate fit precisely into this model. Juana Gómez failed in her wifely responsibilities, choosing to pray the Rosary rather than prepare Villate's food. Thus, Villate, infuriated by what he perceived as her deficiency as a wife, fell victim to a blasphemous rage.[84] As such, the overriding attitude of colonial Mexican society propounded that "women's verbal restraint would guarantee the maintenance of domestic peace, the enactment of feminine Christian decorum, and the preservation of gender hierarchy and social order."[85] Further, on those occasions when women actively blasphemed, many instances involved issues of sexual morality, and there existed a close relationship between female blasphemy and perceived sexual misconduct.[86] The 1572 case of Teresa Rodriguez involved the Virgin Mary and illustrated this relationship between blasphemy and sexual morality.

On August 3, 1572, a peddler named Melchor de Aranda reported Teresa Rodriguez to the Mexican Inquisition. According to Aranda's story, he stopped to sell his goods at an inn owned by Rodriguez. As he transacted with another customer, selling the customer small figurines of Jesus Christ and the Virgin Mary, Rodriguez reportedly regarded the figure of the Virgin and said, "This

79. Ibid.

80. Asunción Lavrin, "Sexuality in Colonial Mexico: A Church Dilemma," in *Sexuality and Marriage in Colonial Latin America*, ed. Asunción Lavrin (Lincoln: University of Nebraska Press, 1989), 65.

81. Villa-Flores, 110

82. Norman Pittenger, *Our Lady: The Mother of Jesus in Christian Faith and Devotion* (London: SCM Press, 1996), 36.

83. Villa-Flores, 109.

84. "Inquisition Trial and Proceedings," 211–12.

85. Villa-Flores, 109.

86. Ibid., 111.

one is good to hang from my pubic hair."[87] Then, seeing the figure of Christ, claimed, "And this other one is good to put in my ass!"[88]

The Mexican tribunal responded harshly. The Holy Office sentenced Rodriguez to attend a penitential mass while barefoot; to process through town on a donkey, gagged and naked to the waist, while a crier proclaimed her crime; and to receive one hundred lashes. The Inquisition also exiled her from the archbishopric of Mexico for four years.[89]

The case of Teresa Rodriguez indicated the views and perceptions of the inquisitors concerning the disturbing instances of female blasphemy. The Mexican tribunal recognized not only Rodriguez's disturbing religious degradation of the Virgin and her son but also the woman's unacceptable sexual attitude and conduct. For the Mexican Inquisition, female blasphemy certainly entailed religious irreverence, but in a woman's impious and uncouth speech, the Holy Office additionally acknowledged a dangerous and unacceptable act of gender subversion.[90]

Men, on the other hand, frequently blasphemed in order to affirm their masculinity and present themselves in a masculine manner. Villa-Flores described male blasphemy in New Spain as "not only a verbal resource for the expression of emotions . . . but also a language of combat, negative reciprocity, sexual assertiveness, and confrontation embraced by Spanish men in colonial Mexico to project an image of strength, bravery, and maleness."[91]

As a result, the Virgin Mary frequently became embroiled in male blasphemy and often became the object of men who blasphemed in an attempt to woo women and boast of their own virility and manliness. In 1614, for example, Juan de Campos denounced Juan de Azpitia to the Mexican Inquisition for telling a young woman that he believed her "more beautiful than God's mother" and, while embracing the woman, proclaiming, "What a hug is missing here, God the Father!"[92] The Holy Office reacted by sentencing Azpitia to hear Mass with a gag in his mouth, a rope around his neck, and a candle in his hand; to be paraded on a donkey; to receive one hundred lashes; and to accept banishment from Mexico City for five years.[93]

Two specific cases directly concerning the Virgin Mary and the sexual potency of certain Spanish men occurred in 1610 and 1691. The former case involved a man named Diego de León. While having a conversation with

87. Villa-Flores, 112.
88. Ibid.
89. Ibid.
90. Ibid., 113.
91. Ibid., 39.
92. Villa-Flores, 52-53.
93. Ibid., 53.

other men concerning a certain group of women in Mexico City, León reportedly expressed with great enthusiasm his desire "to screw all the women in the world" and even "to screw the Virgin in the air."[94] In the latter case, Don Bernardo de Benavente Quiñones similarly declared his masculinity by asserting that he "would screw even the Virgin" and describing the Virgin as "a whore like all women."[95]

Blasphemy therefore played an important role for notions of both femininity and masculinity in New Spain, and both sexes employed blasphemy for specific ends. Slaves—both male and female—likewise uttered this dangerous speech as a strategy of resistance and survival in horrendous working and living conditions.[96] For individuals of various social status and race, blasphemy proved an important tool for affirming, enhancing, or attempting to alter one's social identity in colonial New Spain.

The Virgin Mary was often implicated in blasphemous statements from men and women, free individuals and slaves. For men, blaspheming against the Virgin, especially in a sexual manner, became a symbolic representation of one's masculinity and potency. A man in colonial New Spain could seemingly make no higher claim to prove his virility than assert his desire to debase the most unblemished and unattainable of all women.

For women, blasphemy represented a failure to achieve the ideals of female Christianity and the overall expectations of the female gender.[97] Ironically, in many cases, women who blasphemed had no apparent intention to adhere to the guidelines of Christian femininity but rather uttered their blasphemous oaths in an attempt to forcefully fight against male domination in Mexico and the subsequent misogynistic stereotypes that characterized women as the fragile, weak sex.[98] Women, like men, recognized the power inherent in fiery speech, and though the crime of blasphemy resulted, at times, in harsh punishments and severe consequences, both sexes sacrificed the safety of virtuous, pure speech for the opportunity to assert themselves and prove their inherent authority as strong-willed and dynamic human beings.

Conclusion

While the Inquisition in Spain and its counterpart in Mexico sought to curb, control, and ultimately eradicate blasphemy from the areas in which each operated, the Spanish and Mexican tribunals dealt with rather different

94. Ibid.
95. Ibid.
96. Ibid., 132.
97. Villa-Flores, 126.
98. Ibid., 125-26.

cases and types of blasphemy. As such, the means and methods used by the Spanish Inquisition fashioned themselves in distinct manners, and the Spanish inquisitors enacted their authority in an attempt to produce the religious orthodoxy that the Spanish Crown ardently desired. The Spanish Inquisition aimed to defend and protect the faith of the Catholic Church and to return its lost, misguided members to spiritually and doctrinally sound ways of thinking and acting. The Good Shepherd—Jesus Christ, the foundation of the Church itself—came to seek and save the lost, to cure and restore the unwell. The Inquisition, naturally, adopted a similar *raison d'être*. The protection of Spanish Catholics from blasphemy became one essential part of the Spanish Inquisition's broad mission.

The Holy Office in Mexico likewise concerned itself with the spiritual health of its Catholic population, but the cases of blasphemy presented before the Mexican tribunal betrayed problems beyond religious orthodoxy. Blasphemy in New Spain operated as a tool employed by men and women, both slave and free, to assert their individual wills against a vast, powerful, sometimes hostile societal backdrop.

Blasphemy in New Spain became entangled in notions of gender hierarchy and sexual morality, in standards of masculinity and femininity, and in societal relationships between slaves and the authority of church and state. While these matters may not have directly contradicted the doctrines and dogmas of the Catholic Church, they nonetheless concerned the Mexican Inquisition because they played an important role in colonial Mexican society and influenced the societal landscape as a whole. Christian standards demanded to be upheld, for the spiritual benefit of the individual soul, the Catholic Church, and the societal fabric of the colony of New Spain as a whole.

The Catholic Church held Mary in the heights of exaltedness. Yet precisely because of this, the Marian doctrines of the Church became the source of controversy among Old Christians and New Christians alike. In many ways, then, these doctrines became an easy and popular target for blasphemers, and the Virgin Mary herself became a figure subject to extensive degradation.

Despite its best attempts, the Inquisition succeeded in eradicating blasphemy neither in Spain nor in colonial Mexico. Blasphemy against the Virgin Mary, against God, and against the Church proved unstoppable forces. But did the Inquisition truly believe itself capable of preventing such a pervasive act in the first place?

The sin of blasphemy existed for thousands of years before the Inquisition and had seemingly ingrained itself in the fabric of human existence and interaction. While blasphemy did entail a fundamentally religious problem, given the trials and cases discussed, it also related to underlying societal and cultural

factors. Regardless, in their dealings with the dangerous speech of blasphemy and the fiery tongues of those who dared to speak it, the Spanish and Mexican Inquisitions left a rich legacy detailing the intricacies of Spanish society, the conflicts within the Catholic religion, and the endlessly fascinating words and actions of the human creature.

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Natural and Applied Sciences

Josh Gooch

Finding an Equation for the Area of Regular Polygons and Stars

Abstract

In mathematics, area refers to the number of square units that can fit inside a closed, two-dimensional figure. Throughout history, mathematicians have developed equations that efficiently computed the area of common shapes, such as triangles and circles. Eventually, as integral calculus was developed, mathematicians were also able to determine the exact area of shapes containing curves.

The primary purpose of this paper is to add a new equation to the pantheon of known area formulae. This is an equation for the area of a star containing five or more points. Even though a star consists of series of triangles and a polygon, its area can still be expressed as a multiple of a constant (a regular number) and the square of its side length. The contents of this article will serve as a logical proof of the equation that yields the area of a star.

Introduction

Stars are ever-present shapes. They are present in nearly all historical cultures and are just as relevant today—even making fifty distinct appearances on our nation's flag. Though they may be perceived as sacred religious or national symbols, they also happen to harbor abundant mathematical significance. I intend to prove that regardless of the number of points a star has, the area of the star can be found purely in terms of the length of one of its sides. My equation for the ***exact area*** of a star with n-points and a side length x is given by the expression below:

$$\mathrm{A} = nx^2\left(\frac{\cos\left(\frac{360^\circ}{n}\right)}{\tan\left(\frac{180^\circ}{n}\right)}\right)$$

I will also assert the area of an n-pointed star with side length x can be closely approximated, within a thousandth of a percent, by the equation

$$\mathrm{A} \approx x^2\left(\frac{315n^8 - 630n^6\pi^2 + 210n^4\pi^4 - 28n^2\pi^6}{315n^6\pi + 105n^4\pi^3 + 42n^2\pi^5 + 17\pi^7}\right)$$

The methods used to arrive at these equations draw from many different mathematical fields ranging from high school geometry to calculus. All of the theorems and steps used to arrive at these equations have been explicitly defined, so pure logical reasoning can lead to the conclusions listed above.

Furthermore, all angles in Part I and Part II are assumed to be in degrees. The angles used in Part III are in radians.

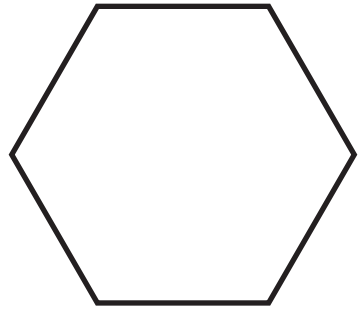
Contents

For the benefit of the reader, brief reviews of various mathematical concepts used throughout the proof have been included in the beginning section.

The main contents of the rest of the paper will consist of determining the area of a regular polygon, the exact area of a star, and approximating the area of a star using power series.

Geometry Review

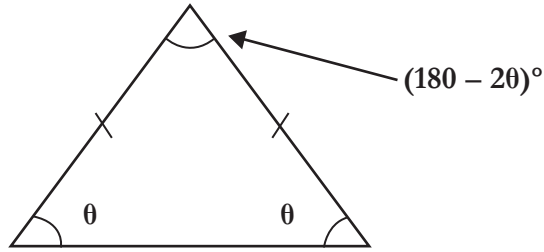
I. A *regular polygon* is a polygon with congruent sides and interior angles. The sum of the interior angles of a regular polygon with n sides is $(180n - 360)°$:



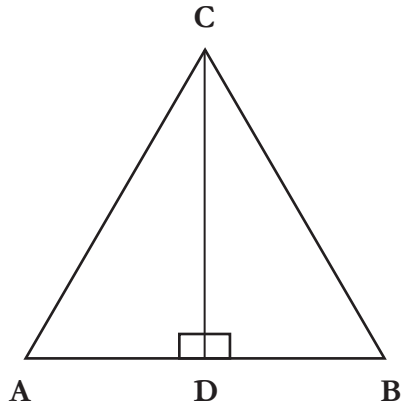
A regular hexagon. The sum of its interior angles is $(180(6) - 360)° = 720°$.

II. Two triangles can be proven congruent if they share three common sides. They can also be proven congruent if they have two congruent sides and a congruent angle between those two sides. These are referred to as the SSS and SAS theorems of triangle congruence, respectively.

III. The two base angles of an isosceles triangle are congruent. Since there are 180° in a triangle, the third angle in an isosceles triangle is equivalent to $(180 - 2\theta)°$, given that θ is one of the congruent base angles:



IV. A *perpendicular bisector* bisects an angle and a side of a triangle. The line meets the side of the triangle at right angles:



Perpendicular bisector CD splits AB into equal lengths AD and BD. It also creates two congruent angles, ∠ACD and ∠BCD out of ∠ACB.

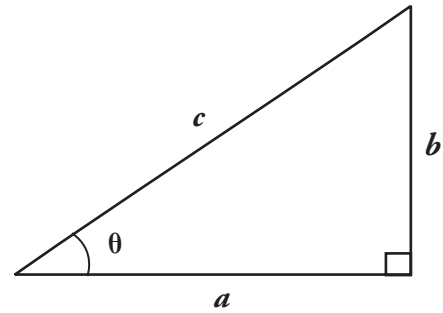
Trigonometry Review

I. The unknown lengths of a right triangle can be determined using the *sine*, *cosine*, and *tangent* functions, given that one of the sides and one of the acute angles of the triangle is known. Each trigonometric function can be expressed as a ratio between two side lengths of a triangle, relative to a known angle θ:

$$\sin\theta = \frac{\text{opposite leg}}{\text{hypotenuse}} = \frac{b}{c}$$

$$\cos\theta = \frac{\text{adjacent leg}}{\text{hypotenuse}} = \frac{a}{c}$$

$$\tan\theta = \frac{\text{opposite leg}}{\text{adjacent leg}} = \frac{b}{a}$$



II. A *trigonometric identity* is an equation involving any of the six trigonometric functions that always holds true, regardless of the angle that is used in the calculation. These identities are primarily used for simplification purposes—making highly convoluted expressions much more concise. Some of the most frequently used trigonometric identities are shown below, which are applied near the end of the paper when simplifying the star area equation:

$$\sin^2 x + \cos^2 x = 1, \qquad \text{for all } x$$

$$\sin 2x = 2\sin x \cos x\,, \quad \text{for all } x$$

$$\cos 2x = \cos^2 x - \sin^2 x\,, \quad \text{for all } x$$

$$\sin x = \sin(180° - x)\,, \quad \text{for all } x$$

$$\tan x = \frac{\sin x}{\cos x}\,, \quad \text{given that } x \text{ is not an odd integer multiple of } 90° \left(\text{or } \frac{\pi}{2} \text{ radians}\right)$$

Power Series Review

I. Sometimes, certain mathematical functions or operators need to be *approximated* for computational purposes. One way of doing so is by using a power series, an infinite sum of algebraic terms with varying coefficients and degrees. An example is given below for $f(x) = e^x$:

$$e^x = \sum_{n=0}^{\infty} \frac{1}{n!} x^n = 1 + x + \frac{x^2}{2} + \frac{x^3}{6} + \cdots$$

It is not necessary to use an infinite amount of terms; however, using more terms will yield a more accurate answer. For instance, suppose the value of e^2 were to be approximated using a power series containing four terms:

$$e^x \text{ (4 terms)} \approx 1 + x + \frac{x^2}{2} + \frac{x^3}{6}$$

$$e^2 \text{(4 terms)} \approx 1 + 2 + \frac{(2)^2}{2} + \frac{(2)^3}{6} = 6.\overline{3}$$

The actual value of e^2 is roughly 7.389, so more terms should be used in the expansion for a more accurate answer. Now consider a power series for e^x containing six terms:

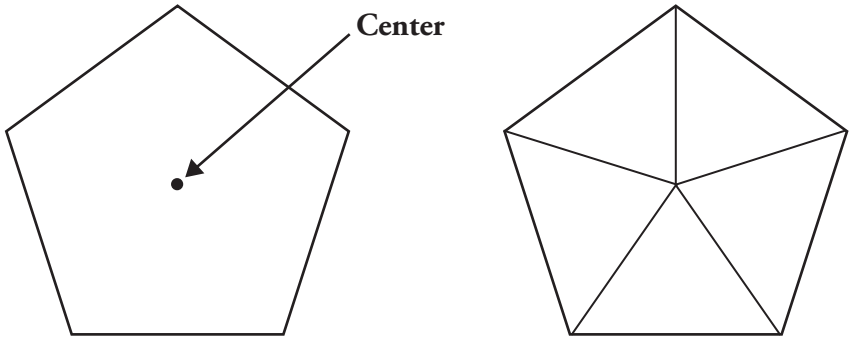
$$e^x \text{ (6 terms)} \approx 1 + x + \frac{x^2}{2} + \frac{x^3}{6} + \frac{x^4}{24} + \frac{x^5}{120}$$

$$e^2 \text{ (6 terms)} \approx 1 + 2 + \frac{(2)^2}{2} + \frac{(2)^3}{6} + \frac{(2)^4}{24} + \frac{(2)^5}{120} = 7.2\overline{6}$$

Though still not quite exact, 7.26 is considerably closer to the true value of e^2 than 6.3. Hence, using more terms in a power series will better approximate any given function. The actual process by which power series are generated for various functions is quite complex and not essential to understanding their purpose in this paper.

Part I: An Equation for the Area of a Regular Polygon

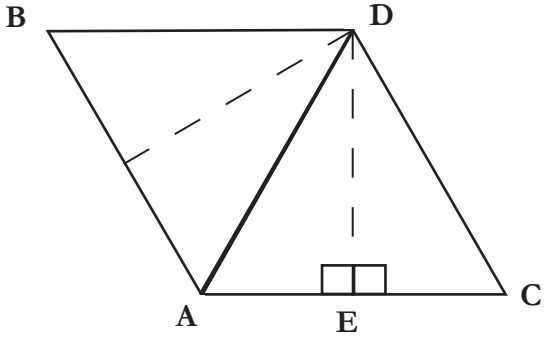
To begin this proof, an equation for the area of a regular polygon with n sides must be derived. A regular polygon with its center marked is shown below. If a line is drawn from each of the polygon's vertices to its center, the polygon is subdivided into n triangles:



This regular pentagon can be divided into five triangles, since it has five vertices that are all connected to its center.

It is intuitive that the sum of the areas of the n triangles is equivalent to the area of the entire polygon. To make this summation easier, it must be established that all of the triangles are congruent to each other. Then, the area of the polygon can be expressed as an integer product of the area of one of the triangles. The proof on the following page shows that the interior triangles of the polygon are equilateral and therefore congruent.

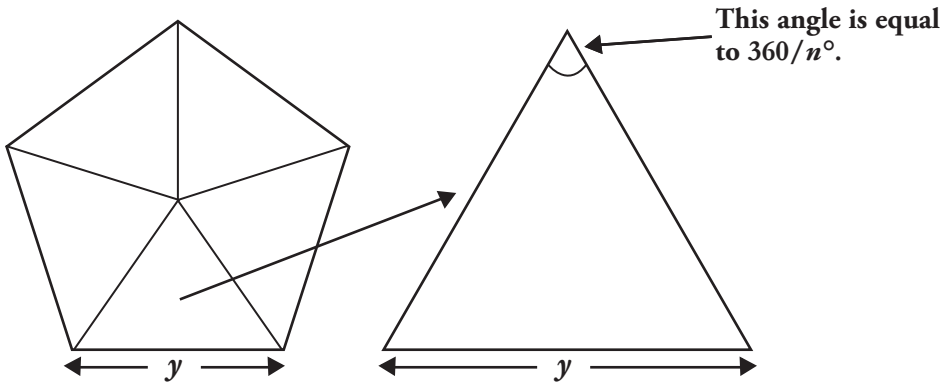
Two triangles from the interior of the polygon are shown below. Points A-D are on the vertices of the triangles. Perpendicular bisector E is drawn in from point D to the midpoint of AC. Below is a tabular arrangement of arguments that prove ΔADC is congruent to ΔABD:



Argument	Defense
AE ≅ CE	Given, Perpendicular Bisector
DE ≅ DE	Reflexive Property of Congruence
∠AED ≅ ∠CED	Right Angles
ΔAED ≅ ΔCED	SAS Theorem of Congruence
CD ≅ AD	CPCTC (the corresponding sides of congruent triangles are congruent to each other)
AD ≅ BD	Each Triangle is Isosceles
AC ≅ AB	Given, Def. of Regular Polygons
ΔADC ≅ ΔABD	SSS Theorem of Congruence

Since the inner triangles of a regular polygon have been shown to be congruent to each other, an equation for the area of one of the triangles can be found and simply multiplied by *n* in order to calculate the area of the entire polygon.

Consider the polygon with a side length y. One of its interior triangles is placed next to it. Since the angle at each inner triangle's apex makes a full circle, each angle has a measure of $360/n°$:



If a perpendicular bisector is drawn from the triangle's apex to the midpoint of the base, all the necessary components for computing the area of the triangle are in place. Points A, B, C, and D are labeled on the triangle below for reference.

Since the perpendicular bisector bisects Angle ACB into two equal angles, the measure of angle ACD is half of $360/n°$, or $180/n°$.

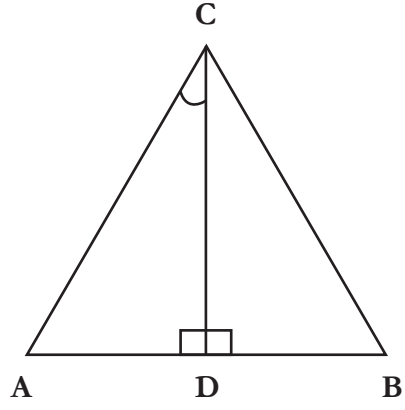
Since the area of the triangle is equivalent to half of the product of the base and the height, trigonometric relationships must be applied in order to write CD in terms of AD. Through proper substitutions, the area of the triangle can be written purely in terms of the side length AB and the angle $180/n°$:

$$A = \frac{1}{2}(AB \times CD)$$

$$A = \frac{1}{2}(2AD \times CD)$$

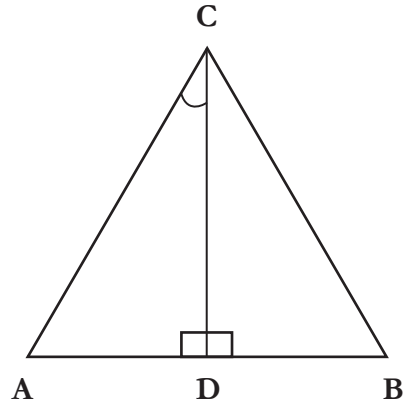
$$\tan\left(\frac{180}{n}\right) = \frac{AD}{CD}$$

$$CD = \frac{AD}{\tan\left(\frac{180}{n}\right)}$$



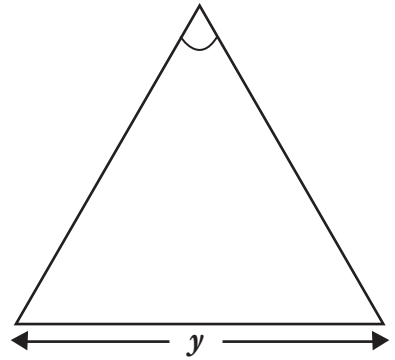
$$A = \frac{1}{2}(2AD)\left(\frac{AD}{\tan\left(\frac{180}{n}\right)}\right)$$

$$A = \frac{AD^2}{\tan\left(\frac{180}{n}\right)}$$



$$A = \frac{\left(\frac{1}{2}AB\right)^2}{\tan\left(\frac{180}{n}\right)}$$

$$A = \frac{AB^2}{4\tan\left(\frac{180}{n}\right)}$$

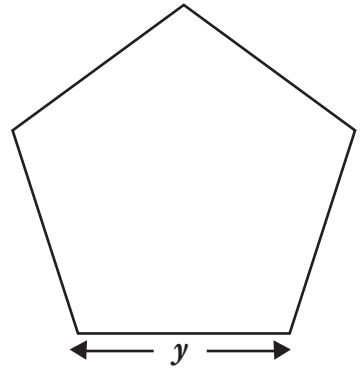


Originally, side AB was equivalent to the polygon's side length *y*. Making one final substitution, the area of the triangle is

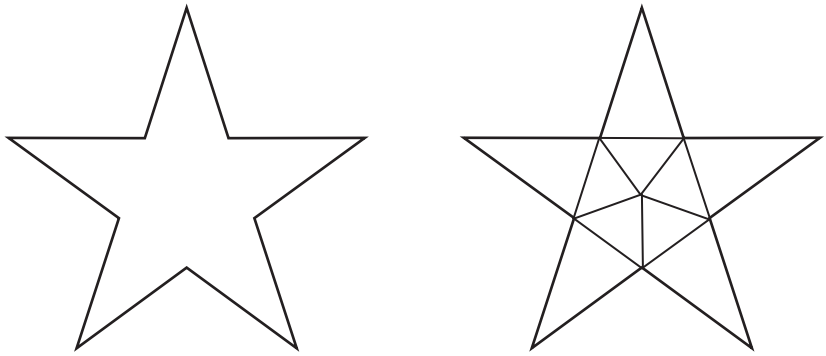
$$A = \frac{y^2}{4\tan\left(\frac{180}{n}\right)}$$

Since a polygon has *n* interior triangles, it follows that the area of any polygon with a side length *y* and *n* sides has an area of

$$A = \frac{ny^2}{4\tan\left(\frac{180^\circ}{n}\right)}$$



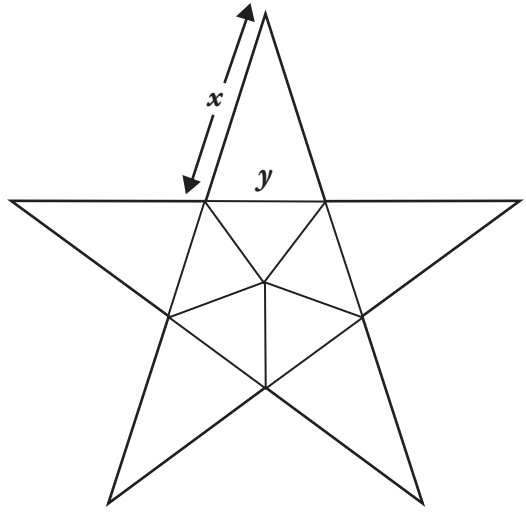
To see how this equation is related to stars, a star must be broken up into component shapes. As seen below, a star with n points consists of n triangles and a regular polygon with n sides. An example of such is given below:



This five-pointed star can be broken into five component triangles and a five-sided regular pentagon.

Part II: The Area of an *N*-pointed Star

Clearly, the area of the star will be equivalent to the sum of the areas of its individual component shapes. However, if the area of a star is to be written purely in terms of its side length, a great amount of algebraic manipulation is required. If the interior pentagon's interior length remains y and the star's side length is equated with x, the two variables can be related using trigonometry:

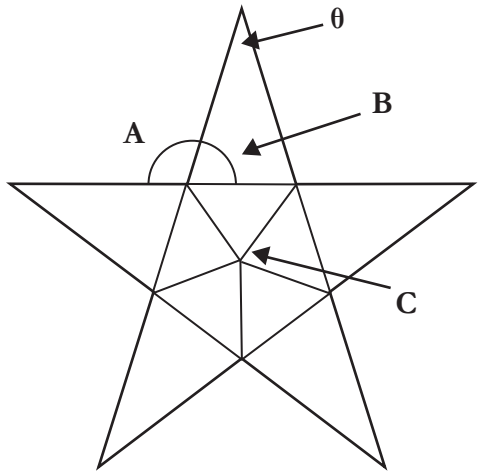


In order to relate x and y, the angles of these triangles must be numerically analyzed. To do so, an expression for the angle labeled θ in the following diagram must be determined. Angles that will be significant to the deductions have been labeled A, B, and C.

The first major step is finding an expression for Angle A. Angle A makes a vertical angle with one of the polygon's interior angles, so they are congruent.

The sum of a polygon's interior angles is equivalent to $(180n - 360)°$, so it follows that Angle A is $(180n - 360)°/n$, or $(180 - 360/n)°$.

Angle B forms a linear pair with Angle A; in other words, their measures sum to 180°. Angle B is therefore equal to $(180 - (180 - 360/n))°$, which simplifies to $(360/n)°$.



Angle B is one of the base angles of an isosceles triangle containing θ. Since the angles of a triangle should sum to 180°, it is clear that

$$\frac{360}{n} + \frac{360}{n} + \theta = 180^{\circ}$$

Solving the equation for θ, we are left with

$$\theta = \frac{180n - 720}{n} = 180 - \frac{720}{n}$$

From the first section of the proof, $\angle C$ was shown to be equal to $360°/n$. Since $720°/n$ is twice that expression, it is mathematically valid to rewrite θ as $180° - 2(\angle C)$. A known theorem from trigonometry states that the area of a triangle with side lengths a and b and an angle θ in between them is equivalent to

$$A = \frac{1}{2}ab\sin\theta$$

The previously shown star has a side length x with an apex angle of $(180 - 2(180/n))°$, so the area of the triangles surrounding the regular polygon

is equivalent to

$$A = \frac{n}{2}x^2 \sin\left(180 - \frac{720}{n}\right)$$

Adding up the areas of the polygon and the triangles, we are left with

$$A = \frac{n}{2}x^2 \sin\left(180 - \frac{720}{n}\right) + \frac{ny^2}{4\tan\left(\frac{180}{n}\right)}$$

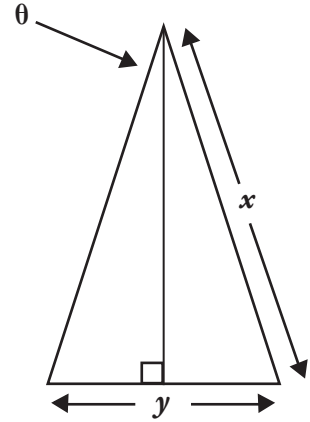
There is now a general equation for the area of the star, but it is still in terms of two variables, x and y. To resolve this issue, consider one of the star's triangles that has both x and y as side lengths.

The base angle of the triangle was proven to be $360/n$, and if a perpendicular bisector is drawn in, y is cut into equal segments of $y/2$.

A cosine ratio can be applied to one of the base angles, finally uniting x and y:

$$\cos\left(\frac{360}{n}\right) = \frac{y}{2x}$$

$$y = 2x\cos\left(\frac{360}{n}\right)$$



Making one final substitution and simplifying, the area of an n-pointed star is given by

$$A = \frac{n}{2}x^2 \sin\left(180 - \frac{720}{n}\right) + \frac{4nx^2\cos^2\left(\frac{360}{n}\right)}{4\tan\left(\frac{180}{n}\right)}$$

$$A = \frac{2nx^2 \sin\left(180 - \frac{720}{n}\right)\tan\left(\frac{180}{n}\right) + 4nx^2\cos^2\left(\frac{360}{n}\right)}{4\tan\left(\frac{180}{n}\right)}$$

$$A = nx^2\left(\frac{\sin\left(\frac{720}{n}\right)\tan\left(\frac{180}{n}\right)+2\cos^2\left(\frac{360}{n}\right)}{2\tan\left(\frac{180}{n}\right)}\right)$$

The trigonometric component of this equation is rather complicated; however, identities can be applied to simplify the trigonometric functions even further. Letting $\theta = 180/n°$, the expression in the parentheses is equal to

$$\frac{\sin 4\theta \tan\theta + 2\cos^2 2\theta}{2\tan\theta}$$

$$= \frac{2\sin 2\theta \cos 2\theta \tan\theta}{2\tan\theta} + \frac{2\cos^2 2\theta}{2\tan\theta}$$

$$= \sin 2\theta \cos 2\theta + \frac{\cos^2 2\theta}{\tan\theta}$$

$$= 2\sin\theta\cos\theta\cos 2\theta\left(\frac{\tan\theta}{\tan\theta}\right) + \frac{\cos^2 2\theta}{\tan\theta}$$

$$= \frac{2\sin\theta\cos\theta\cos 2\theta\tan\theta}{\tan\theta} + \frac{\cos^2 2\theta}{\tan\theta}$$

$$= \frac{2\sin\theta\cos\theta\cos 2\theta\left(\frac{\sin\theta}{\cos\theta}\right) + \cos^2 2\theta}{\tan\theta}$$

$$= \frac{2\sin^2\theta\cos 2\theta + \cos^2 2\theta}{\tan\theta}$$

$$= \frac{\cos 2\theta\,(2\sin^2\theta + \cos 2\theta)}{\tan\theta}$$

$$= \frac{(\cos 2\theta)(2\sin^2\theta + \cos^2\theta - \sin^2\theta)}{\tan\theta}$$

$$= \frac{\cos 2\theta\,(\sin^2\theta + \cos^2\theta)}{\tan\theta}$$

$$= \frac{\cos 2\theta}{\tan\theta}$$

Here, various trigonometric identities are being used to the above equation. The ones used throughout the transformation are

$$\sin^2 x + \cos^2 x = 1$$
$$\sin 2x = 2\sin x \cos x$$
$$\cos 2x = \cos^2 x - \sin^2 x$$
$$1 / \tan x = \cos x / \sin x$$

Thus, the expression for the area of a star can be simply expressed as

$$\mathrm{A} = nx^2\left(\frac{\cos\left(\frac{360°}{n}\right)}{\tan\left(\frac{180°}{n}\right)}\right)$$

There is now a much more succinct equation for the area of an *n*-pointed star with side length *x*. The expression in the parentheses can be rewritten as a decimal, so the formulas for the area of a star can be simplified as the product of a coefficient and the square of its side length.

For example, when $n = 5$, the entire equation is approximately equal to

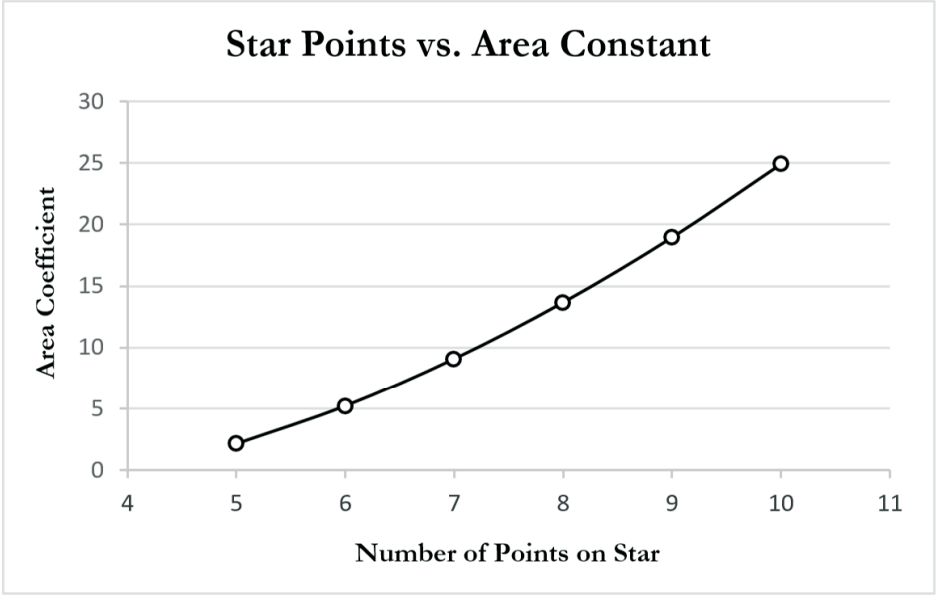
$$A\ (5\text{ pointed star}) \approx 2.13x^2$$

The table below gives the different constants for n = 5, 6, 7, 8, 9, and 10 points:

Number of Points on Star	Constant	Approximate Area of a Star
5	2.126627021	$2.1266x^2$
6	5.196152423	$5.1962x^2$
7	9.062829399	$9.0628x^2$
8	13.65685425	$13.6569x^2$
9	18.94220829	$18.9422x^2$
10	24.89898285	$24.8990x^2$

Part III: Star Area Approximation Using Power Series

If the coefficient of the x^2 term is graphed against the number of points on the star n, the following curve is created:



Another question is whether this curve can be expressed as a power series, an infinite sum of algebraic variables with varying degrees and coefficients. If so, the area of a star can be approximated without trigonometric functions.

It should be noted that if the power series are applied, the equation must be in radians, rather than degrees. Using the conversion factor 2π radians = 360°, the equation for the area of a star in radian form is given by

$$\mathrm{A} = nx^2\left(\frac{\cos\left(\frac{360°}{n}\right)}{\tan\left(\frac{180°}{n}\right)}\right) \sim nx^2\left(\frac{\cos\left(\frac{2\pi}{n}\right)}{\tan\left(\frac{\pi}{n}\right)}\right)$$

The functions $\cos(2\pi/n)$ and $\tan(\pi/n)$ will be expanded using the following power series as a guide:

$$\cos x = \sum_{n=0}^{\infty} \frac{(-1)^n}{(2n)!} x^{2n} = 1 - \frac{x^2}{2} + \frac{x^4}{24} - \frac{x^6}{720} + \cdots$$

$$\tan x = \frac{\sum_{n=0}^{\infty} \frac{(-1)^n}{(2n+1)!} x^{2n+1}}{\sum_{n=0}^{\infty} \frac{(-1)^n}{(2n)!} x^{2n}} = x + \frac{x^3}{3} + \frac{2x^5}{15} + \frac{17x^7}{315} + \cdots$$

When the two series are expanded to four terms each, they closely converge with their original graphs for all $n \geq 3$, the minimum number of sides a polygon can have:

$$\cos\left(\frac{2\pi}{n}\right) \approx 1 - \frac{2\pi^2}{n^2} + \frac{2\pi^4}{3n^4} - \frac{4\pi^6}{45n^6} \quad (n \geq 3)$$

$$\tan\left(\frac{\pi}{n}\right) \approx \frac{\pi}{n} + \frac{\pi^3}{3n^3} + \frac{2\pi^5}{15n^5} + \frac{17\pi^7}{315n^7} \quad (n \geq 3)$$

Substituting these expansions into the area equation yields

$$A = nx^2\left(\frac{\cos\left(\frac{360°}{n}\right)}{\tan\left(\frac{180°}{n}\right)}\right) \gg nx^2\left(\frac{1 - \frac{2\pi^2}{n^2} + \frac{2\pi^4}{3n^4} - \frac{4\pi^6}{45n^6}}{\frac{\pi}{n} + \frac{\pi^3}{3n^3} + \frac{2\pi^5}{15n^5} + \frac{17\pi^7}{315n^7}}\right)$$

After simplifying, an equation that approximates the area of a star with n-points and side length x is finally reached.

$$Area \approx x^2 \left(\frac{315n^8 - 630n^6\pi^2 + 210n^4\pi^4 - 28n^2\pi^6}{315n^6\pi + 105n^4\pi^3 + 42n^2\pi^5 + 17\pi^7} \right)$$

This equation contains varying powers of π, a mathematical constant often used for calculating the area of circles.

A table below has been generated for different values of n in order to demonstrate the precision of the above equation. A side length of one has been assumed for simplicity. According to the final column, the approximation becomes more precise as n gets larger.

Points	Trigonometric Area	Power Series Area	Percent Error
5	2.126627021	2.126747191	0.0057
6	5.196152423	5.19643918	0.0055
7	9.062829399	9.063009899	0.0020
8	13.65685425	13.65695619	0.00075
9	18.94220829	18.94226599	0.00030

Thus, using a variety of mathematical concepts and techniques, a new, straightforward equation for determining the area of n-pointed stars with a side length of x has been successfully derived. The same applies to regular polygons with n sides and side length x. The approximation aspect of the star equation has also determined a new use for the mathematical constant π, often thought to be related to circles. This equation can also be applied to various other fields such as engineering, architecture, or graphic design, where knowing the area of a star or volume of a solid with a star-shaped base may be necessary. Though various disciplines may find utility in these theorems, they primarily serve to expand the widening scope of plane geometry.

Elizabeth Wood

An Assessment of the Effects of Offshore Wind Farms on Marine and Terrestrial Species

Abstract

In recent years, renewable forms of energy have become increasingly attractive as a means of reducing carbon emissions. In particular, the offshore wind power industry has rapidly expanded, causing researchers to question what effects offshore turbines have on marine and terrestrial organisms. Although research is still relatively sparse in this field, the most sensitive organisms have been identified and studied. As an expansion to the previous assessment titled "Literature Review on the Effects of Offshore Wind Turbine Noise on Marine Mammals" (Wood, 2014), this paper assesses the research on the effects of offshore wind power on marine fish, marine mammals, seabirds, and bats. By compiling the most recent research from laboratory and in situ experiments, the potential positive and negative effects on these organisms have been identified.

After organizing and analyzing the research, the best method of approaching issues with offshore wind development was deduced. Most research only examines one species or one area of interest, but by compiling all of the research, an overall strategy was revealed. By utilizing communication between wind farm developers, researchers, and regulatory bodies, detailed impact assessments on proposed and current wind farms can be prepared. Impact assessments should be used to identify the most sensitive species in the area of interest and what positive or negative impacts might affect these species. Information on a range of mitigation techniques was also extracted from the research. Based on the impact assessments, mitigation techniques for the negative effects should be chosen accordingly and applied. By continuing research and monitoring current wind farms, knowledge gaps about this novel form of alternative energy will begin to close and improved mitigation techniques will reduce negative impacts to the marine and terrestrial organisms living near wind farms.

Introduction

The increasing pressure to decrease carbon emissions has led to an expansion in renewable energies. Offshore wind power is one of the renewable energy options that is rapidly being exploited. This is due partly to Europe's support in expanding the offshore wind power industry. The first offshore wind farm was installed in 1991 and the first commercial-sized offshore wind farm was completed in 2001 (Bailey, Brookes, & Thompson, 2014; Matutano, Negro, López-Gutiérrez, Esteban, & Hernández, 2014). By 2012, 5,000 megawatts (MW) worth of offshore turbines were installed (Matutano et al., 2014). Cur-

rently there are over 69 offshore wind farms just in Europe. With technology constantly advancing, higher-capacity wind turbines are being developed and wind farms are being installed farther from shore in deeper water (Bailey et al., 2014).

The expansion of offshore wind farms has caused an increase in anthropogenic, or manmade, disturbances for marine and terrestrial organisms (Merchant, Pirotta, Barton, & Thompson, 2014; Pine, Jeffs, & Radford, 2014). Researchers have tried to assess the risks these organisms and their ecosystems might encounter, but with the novelty of offshore wind power there is still uncertainty surrounding many of the potential consequences (Bailey et al., 2014; Merchant et al., 2014; Matutano et al., 2014). Since around 2000, research concerning offshore wind power has evolved to become more precise and specific in response to new information (Bergström et al., 2014). From what is known thus far about the effects of offshore wind power, a few recommendations have been made on how to proceed with assessing proposed and operational sites. After identifying the range of possible biological effects from a proposed site, it is suggested that at least two years be spent collecting data about species occurrences and key populations. Risk assessments should include information from other offshore industries about possible effects and mitigation techniques. Whether using models or actual wind farms, the responses of species to construction and operation need to be measured (Bailey et al., 2014). Regulatory bodies currently require that the sound emitted from offshore wind projects be assessed for impacts on marine organisms (Pine et al., 2014). Once the responses and impacts have been identified, there is a need to determine whether the effects are significant on a population level (Bailey et al., 2014; Bergström et al., 2014). Finally, during construction and operation stages, the possible cumulative effects from multiple disturbances and human activities need to be considered. The complexity of assessing the impacts from offshore wind farms requires cooperation and communication between developers, scientists, and regulatory bodies (Bailey et al., 2014; Nabe-Nielsen, Sibly, Tougaard, Teilmaan, & Sveegaard, 2014).

There are three stages of a wind farm: construction, operation, and decommissioning. For each stage, there are potential positive and negative effects. The impacts to marine and terrestrial organisms that researchers are currently concerned with are acoustic disturbances, collisions, habitat alterations and exclusions, changes in the food web, behavioral responses, and masking of communication (Bailey et al., 2014; Pine et al., 2014). The impacts related to the construction stage are acoustic disturbances from pile-driving, behavioral responses, and increased vessel traffic. Although very little research has examined the decommissioning stage, the impacts are expected to be similar to the

construction stage (Bergström et al., 2014). Pile-driving is the main method for securing turbine foundations and requires thousands of loud hammer blows for each pile. During pile-driving, there is about one blow per second, with the noise traveling tens of kilometers away from the construction area. The wavelengths of these loud hits are within the range of hearing for marine mammals and fish, which may respond to the disturbance by changing their behavior (Bailey et al., 2014; Bergström et al., 2014). Fish and marine mammals may experience a range of behavioral changes depending on the species and their level of sensitivity to the acoustic disturbance.

During the operational phase, collisions, habitat alterations and exclusions, changes in the food web, and masking of communication are all possible impacts; however, some of these impacts are potentially beneficial (Bailey et al., 2014; Bergström et al., 2014). Positive impacts are usually associated with habitat alterations that lead to habitat gain (also known as artificial reef effect) for organisms that attach to turbine foundations. Whether habitat gain is positive or negative depends on the existing ecosystem. The artificial reef effect could enhance the abundance of local species, but it could also alter the balance of local biodiversity or provide new habitats for nonindigenous species to thrive (Bailey et al., 2014; Bergström et al., 2014). Potential impacts for each stage will be assessed throughout this paper for fish, marine mammals, seabirds, and bats. Such organisms are among the most sensitive to the pressures from offshore wind farms, and the effects on these organisms from offshore wind turbines should be taken into account when designing wind turbines, proposing sites for new wind farms, and monitoring current wind farms.

Fish

Communities of fish in marine environments are very diverse, with some studies recording up to 100 species regularly seen in areas designated for wind farms (Bergström et al., 2014). So far, studies have mainly focused on offshore areas in Europe, such as the North Sea, and on economically significant fish, such as cod (*Gadus morhua*) and herring (*Clupea harengus*) (Bergström et al., 2014; Reubens, Degraer, & Vincx, 2014). Offshore wind farms have been constructed in coastal waters of many European countries with thousands more turbine installations planned in the next decade (Reubens et al., 2014). With this expansion in mind, it's important to consider all the potential effects offshore wind power can have on the marine fish populations. The effects on fish are the result of wind farm construction, operational noise, electromagnetic fields, and sheltering effects.

The construction stage for wind farms is the riskiest in terms of harming

fish. The length of the construction phase varies depending on the size of the wind farm. One study conducted during the construction of an 18 square kilometers wind farm reported that the construction phase lasted 5 years (Reubens et al., 2014). Most wind farms are constructed using pile driving, which results in extreme underwater noise while the turbine foundations are put in place. The risks associated with extreme noise from pile driving are mortality and tissue damage in fish (Bergström et al., 2014). Several species of fish have endured injuries in experiments that simulated the sounds of pile driving; however, these species tended to recover within less than 2 weeks without having their overall survival affected (Bailey et al., 2014). Laboratory experiments generate high-intensity pile driving sounds inside acoustic chambers, but some in situ field experiments have also been conducted (Debusschere et al., 2014).

In a study by Debusschere et al. (2014), European sea bass (*Dicentrarchus labrax*) were chosen as the focus of an in situ experiment because they are often exploited commercially via fisheries and aquaculture. This experiment studied juvenile sea bass in particular since the early life stages of fish have a higher risk of harm from the impulsive sounds of pile driving. In the study, the juvenile sea bass were exposed to the pile driving sounds at different distances, with the closest juveniles just 45 meters from the construction site. The fish were exposed to between 1,739 and 3,067 pile driving strikes. The control group of fish were not exposed to any pile driving sounds. There were no significant differences in immediate or delayed mortality between the control and exposed groups. Results from this sea bass study were consistent with the results of experiments done in laboratories on common sole larvae (Solea solea), juvenile Chinook Salmon (*Oncorhynchus tshawytscha*), lake sturgeon (*Acipensen fulvescens*), Nile tilapia (*Oreochromis niloticus*), hogchoker (*trinectes maculatus*), and hybrid striped bass (white bass *Morone chrysops* x striped bass *Morone saxatilis*). It was also noted in this experiment that exposure time and sound levels in in situ experiments represent the worst-case scenario. Realistically, juvenile sea bass drift with currents in the ocean and are not stagnant. This would decrease the exposure time and reduce the risk of physiological effects. The exception to this is during periods of minimum current, such as slack tide (Debusschere et al., 2014).

Mortality from pile driving sound exposure has not been identified as a high risk to fish, but other risks, such as internal injuries, have been discovered. Sound pressure thresholds vary among fish species, but if the thresholds for onset of injury are exceeded, then internal injuries may occur. The results of experimentation have shown that exposure to pile driving causes more injuries and injuries of higher severity in physoclist fish species than in physostomous fish species. Fish have the ability to change the volume of their swim bladder

in response to changes in sound pressure levels. Physostomous species are able to adjust their swim bladders faster than physoclist species, resulting in the physoclist species being more susceptible to the harmful effects of high sound pressure from pile driving. Internal injuries can lead to mortality, but if fish survive the injuries then they have the ability to heal as the post-exposure time after pile driving increases (Debusschere et al., 2014).

Once the construction stage is complete, potential effects from the operational stage, such as operational noise, electromagnetic fields, and sheltering, must be considered. At present, the effects of operational noise on fish have not been fully studied. It is believed that the sounds from turbines could mask communication and orientation signals for fish, which in turn could possibly affect foraging, breeding, and migration (Bailey et al., 2014). It is unknown how the operational sounds effect the fitness of early life stages for fish populations. Populations of fish in the early stages of life are important as prey and as recruits into adult populations (Debusschere et al., 2014). Further research into these consequences is recommended and could be assisted by the use of acoustic telemetry, which tracks fish movement and can be used long-term (Bailey et al., 2014). Effects from electromagnetic fields (EMF) on fish also requires more research, particularly because the effects may vary depending on the species of fish present. Cables from the turbines emit EMF when transmitting electricity. EMF from turbines could interfere with fish that utilize EMF for movement, navigation, and detection of prey (Bailey et al., 2014; Bergström et al., 2014). In an impact assessment on EMF, the overall negative impact was rated low, but areas containing fish that are sensitive to EMF, such as cartilaginous fish, were rated higher (Bergström et al., 2014).

Another result of wind farms that may affect fish is sheltering. Fisheries can limit adult and juvenile fish populations. Many offshore wind farms have already prohibited fishing and it has been recommended by research that fishing should not be allowed within any wind farms (Reubens et al., 2014). Boats are also often banned from the wind farm area, which further reduces disturbance and turns offshore wind farms into de-facto marine reserves by providing shelter for fish. The effects of these limitations/exclusions could increase the prey population for top predators and increase the populations of commercial fish (Bailey et al., 2014). Studies have shown that species such as pouting (*Trisopterus luscus*), cod (*Gadus morhua*), and horse mackerel (*Trachurus trachurus*) can live in dense populations close to the turbines (Bergström et al., 2014). Shelter provided by offshore wind farms can also increase the survival rate of fish in early life stages. In this way, wind farms can help protect fish against predators, fishing pressure, and strong ocean currents. This could be seen as a positive effect from wind farms because it would be contrib-

uting to marine conservation and lessening the effects of exploitative fishing.

When the wind turbines are built offshore, their foundations transform softer-bottomed ecosystems into environments with hard substrates (Reubens et al., 2014). This can impact the way the ecosystem functions and its local biodiversity. Reubens et al. (2014) referred to this new component of the ecosystem as "windmill artificial reefs" (WARs) and studied how it effects Atlantic cod and pouting in part of the North Sea. With the addition of WARs, ecosystems may change to attract more fish, including species that were unable to settle in the natural ecosystem. The issue with attraction is whether or not the new ecosystem is able to support production once the fish have settled. Ecological traps can occur when fish encounter a new environment, such as WARs, and cannot determine if it is optimal compared to other accessible areas (Reubens et al., 2014).

Reubens et al. (2014) determined the attraction to WARs from Atlantic cod and pouting by comparing catch per unit effort at WARs, shipwrecks, and sand bottoms. Initially, fish were not attracted to the WARs, but cod were attracted one year after deployment. In fact, more cod were at the WARs in comparison to the other two habitat types. Within the first year of operation, pouting were actually attracted to the WARs more so than the other habitats. This proved the WARs to not be an ecological trap or an inferior ecosystem for the fish. When compared to the other two habitats, the WARs conditions were the same or better. Both cod and pouting had an excess of food, leaving available energy for reproduction and growth. The fish demonstrated high site fidelity and were attracted to the WARs seasonally. The production that was recorded in this study was only on a local scale. Production on local and regional scales needs to be recorded long-term in conjunction with further studies on how WARs affect the behavior of fish (Reubens et al., 2014). Long-term studies with expanded geographical ranges will allow scientists to determine whether or not artificial reefs created by wind farms are beneficial to marine habitats.

Marine Mammals

Aspects of the natural environment, such as natural disturbances, predators, competition, and resource availability, impact marine mammals' fitness (Nabe-Nielsen et al., 2014). The soundscape of this natural environment is altered when anthropogenic noise from (and related to) offshore wind turbines is added. The primary sensory mode of marine mammals is sound, and these anthropogenic noises have the ability to mask acoustic cues used for echolocation and communication (Merchant et al., 2014; Rossi-Santos, 2014). Studies have suggested that marine mammals perceive anthropogenic noise as a risk

and therefore, might avoid the source or allow the noise to affect their decision-making processes (Merchant et al., 2014; Nabe-Nielsen et al., 2014). The added pressure from anthropogenic noise and habitat reconstruction could also lead marine mammals to experience physical stress and behavioral changes in their vocalizations. All of these responses can be costly when they accumulate. Individual mammals can experience reduced fitness, which over time can affect the population as a whole (Merchant et al., 2014). As of now, no studies have assessed the long-term population impacts of marine mammals' responses to offshore wind farms (Bailey et al., 2014).

Although the potential impacts of offshore wind turbine noise on marine mammals are recognized in many studies, baseline noise levels, or the levels of noise that can be safely allowed, have not been set to manage these impacts due to uncertainty on what the baseline levels should be. The Marine Strategy Framework Directive (MSFD) is expected to set baseline levels by 2020, to aid in determining which EU waters can be designated as having "Good Environmental Status" (Merchant et al., 2014). However, baseline noise levels are difficult to ascertain because the effects from offshore wind farms on marine mammals differ based on the species. The species' level of sensitivity, probability of interaction, and level of avoidance in relation to the structures will determine what level of noise that species can endure. To study the responses of a specific species, acoustic methods and GPS tracking are both useful (Bailey et al., 2014).

For example, studies on harbor porpoises have examined their behavioral responses to pile driving sounds by using simulated noise, playback of pile driving sounds, and live conditions. From these studies, the harbor porpoises' zone of responsiveness could reach 20 kilometers or more from the construction site (Bailey et al., 2014; Nabe-Nielsen et al., 2014). The response zone for individual porpoises varies based on the activity the individual was engaged in when the sound started, the ambient noise level, and how the sound travels through the water in that region (Bailey et al., 2014). This variation in responses from just one species in one region illustrates why it is difficult to apply a baseline noise level across many different regions inhabited by many different species. The region in which a wind farm is being built also determines which species are at the greatest risk. For instance, in Europe, impact assessments for marine mammals tend to focus on pinnipeds and smaller cetaceans because these species occur frequently and have a high protection status. In other regions, whales are at a greater risk because they are endangered and have call frequencies which are sensitive to the frequencies created throughout pile driving (Bailey et al., 2014).

Between the construction and operation stages of offshore wind farms, the

construction stage is expected to have the greater impact on marine mammals due to pile driving and a rise in boat traffic. There are other techniques for laying the turbine foundations, but pile driving is the most common. The potential effects from pile driving are hearing damage (temporary or permanent), masking of acoustic cues, and avoidance. At this time, avoidance appears to be the most prevalent (Bailey et al., 2014; Bergström et al., 2014). In a study conducted at the Nysted Offshore Wind Farm, the density of porpoises was greatly reduced during construction, but remained low for several years after the wind farm began operating (Nabe-Nielsen et al., 2014). The behavioral consequences such as avoidance are being studied more, but so far no empirical studies have shown these effects to cause changes in the population. However, as mentioned before, long-term population studies have not been conducted yet (Bailey et al., 2014).

The underwater noise from operational wind turbines is not likely to harm marine mammals or mask acoustic cues, but thus far, studies have only focused on seals and porpoises. Multiple studies have tracked seals with high resolution GPS to determine how wind farms affect their behavior. The GPS showed seals using the wind farms as areas to forage (Bailey et al., 2014; Russell et al., 2014). Russell et al. (2014) studied two species of seals (*Phoca vitulina* and *Halichoerus grypus*) by tracking them within the North Sea to assess their movements around wind turbines. In comparison to the number of individuals tracked, a small proportion used the wind farms. However, if this small proportion is related to the North Sea seal population as a whole (~120,000 individuals for these two species) then it is likely that a much greater number of seals utilize wind farms. The group of seals that did use the structures were comprised of males, females, juveniles, and adults. These individuals also appeared to be in the same condition as the other seals when captured. The data on the seals' movements strongly suggested foraging behavior and showed the seals successfully navigating through the turbines. Most of the seals that foraged for food within the wind farms did so more than once, but they also foraged elsewhere. The repetition indicates that the seals successfully foraged near the turbines. Foraging in other regions shows these seals were not using the wind farms because they were unable to be successful elsewhere. It was hypothesized that the difference between the seals that foraged in the wind farms and the seals that did not is due to the individuals' behavior and their willingness to use new habitats. The wind farms used in this study were new, so it was also theorized that foraging behavior may increase as the artificial reefs continue to develop (Russell et al., 2014).

Another study utilized a simulated model of harbor porpoises in Danish Waters to assess the reactions of the porpoises to fisheries by-catch, noise from

wind turbines, and noise from large ships (Nabe-Nielsen et al., 2014). The individual-based model had the ability to combine the reactions from all the individuals to give a likely scenario of what would happen to the population as a whole. As mentioned before, if marine mammals react to wind turbines, it is usually by dispersing. Dispersal can affect the fitness of marine mammals by excluding the animals from foraging areas and causing energy loss from swimming away (Nabe-Nielsen et al., 2014).

The effects from by-catch and ship noise were included with wind turbine noise in the model because the impacts from all of these disturbances are additive. If other disturbances were introduced into the environment, they would add to the overall impact on the population. The wind turbines included in the simulation corresponded to 179 established turbines and 300 planned turbines, which together formed six wind farms. The operational noise is expected to be audible to porpoises up to a few hundred meters from the turbine. When the established wind turbines were added to the model, the porpoise population size decreased by 10.4% due to the porpoises avoiding the turbines. When noise from ships and planned turbines were included in the scenario, the population size did not decrease any further. The model concluded that although noise from operational wind turbines and ships caused some porpoises to disperse, the noise did not have any long-term implications on the survival or resilience of the harbor porpoise population (Nabe-Nielsen et al., 2014).

An important consideration when assessing this model is "that the simulated effects of noise from wind turbines are based on a worst-case scenario, where it is assumed that turbines are capable of permanently scaring approximately half of the animals away" (Nabe-Nielsen et al., 2014). This reaction is similar to the observation made at the Nysted Offshore Wind Farm, where the porpoise density was very low for several years after operation began. However, a strict correlation between the low porpoise density and turbine noise was not confirmed for this site and has been contradicted by observations at other wind farms. At the Horns Rev offshore wind farm, porpoise densities around the wind farm remained unchanged during operation. Another study in the North Sea revealed higher porpoise densities within the wind farm compared to outside the wind farm during operation (Nabe-Nielsen et al., 2014).

When the deterrence distance of porpoises was changed in the model to reflect a balance between worse-case scenario and the other studies, the population size did not differ significantly (no longer decreased 10.4%) from the scenario without any ships or turbines. For porpoises, and possibly other marine mammals, the deterring effect of noise from turbines could decrease overtime. Dense populations of porpoises are often found in regions with substantial boating traffic, which indicates an acclimation to anthropogenic noise. Harbor

porpoises are common inhabitants of coasts in Europe and North America, so this simulation is applicable to a wide range of regions where wind farms are likely to be built. Individual-based models similar to this could also be used to assess different species and identify ways to manage marine populations (Nabe-Nielsen et al., 2014).

Not all of the underwater noise associated with offshore wind turbines comes directly from the turbines or their construction. It is important to assess how noise from shipping affects marine mammals since the construction of offshore wind farms leads to an increase in vessel traffic. Merchant et al. (2014) examined the effects of anthropogenic and natural noise on marine mammals in two different sites of the Moray Firth Special Area of Conservation (SAC) in the North Sea. The study utilized noise mapping based on Automatic Identification System (AIS) and focused on bottlenose dolphins (*Tursiops truncatus*), although several other species of marine mammals also reside in the area. These species include harbor seals, harbor porpoises, grey seals, and minke whales (*Balaenoptera acutorostrata*) (Merchant et al., 2014).

The two sites chosen—The Sutors and Chanonry—were important regions for foraging for the bottlenose dolphins. Long-term monitoring of the bottlenose population has shown that the population is stable or increasing. This means the current noise level was not a threat to the dolphins' survival. After analyzing the soundscapes of both sites, a noticeable difference was discovered. The Sutors is close to an industrial area and experienced higher levels of shipping traffic. At Chanonry, vessels only passed through occasionally (Merchant et al., 2014). The daily noise exposure from The Sutors was used to determine the rise in noise exposure above natural levels due to ships. Recorded dolphin vocalizations also revealed significant overlap between the noise from passing ships and the frequency and amplitude of their communications. This commonality shows the possibility for ships to mask marine mammal communication. Although the potential is there, whether masking actually occurs and is significant is dependent on the animals' behavior and the extent to which the boat noise reduces the signal-to-noise ratio of the vocalization. Bottlenose dolphins, as well as all odontocetes, rely on echolocation for foraging. Masking would disrupt this activity and could negatively affect fitness. Masking could also have a harmful effect on social interactions since dolphins' vocalizations are used for communicating (Merchant et al., 2014).

The effects from increased shipping noise may differ according to the soundscape the dolphins are accustomed to. Based on plans for future wind farms, The Sutors will have a greater increase in vessel traffic as compared to Chanonry. However, dolphins in The Sutors have already adapted to higher noise levels than in Chanonry and may be effected less by a further increase.

In Chanonry, where the current soundscape is relatively quiet, even a small increase in vessel traffic could greatly alter the soundscape and cause the habitat quality to degrade. Aside from the site differences, increased noise levels in either site could affect the fish and lead to habitat degradation for the dolphins by reducing their prey. Further studies should be conducted to determine the extent to which masking is a threat to marine mammals and how increases in the baseline noise level could affect behavior and habitat (Merchant et al., 2014). As this study showed, evaluating noise from the turbines as well as related noise is important for developing mitigation techniques to protect marine mammals.

Birds & Bats

Many different aspects must be considered when determining the risks offshore wind farms pose to birds and bats. To begin an impact assessment for birds and bats, the populations occurring within the wind farm area must be identified and each species' conservation status needs to be taken into account (Bailey et al., 2014). Even after gathering information about species, estimating impacts from windfarms can be complicated and imprecise. This presents a problem, because developers often rely on impact assessments for permission to construct wind farms. Recent assessments on the predicted consequences for seabirds have caused some projects to be delayed or cancelled altogether (Johnston, Cook, Wright, Humphreys, & Burton, 2014). Fortunately, researchers are developing new tools and techniques for assessments to improve the reliability of predictions. Two of these developments are the Geographic Information System (GIS) tool and the Seabird Mapping and Sensitivity Tool (SeaMaST), which can assist in predicting the sensitivity of certain seabirds to wind farms and how the seabirds will use offshore areas. Density Surface Modelling is another tool which can predict the density of birds in the offshore area of interest. Sensitivity maps that show distributions of sensitive species can be created by combining the species' risks of turbine collision and displacement with their density estimates (Bradbury et al., 2014). Improving the tools and techniques for assessing impacts is especially important now that the number of offshore wind farms is increasing.

Large offshore regions used by many seabirds currently have proposals for wind farms. The United Kingdom is already leasing offshore areas for the third time and the scale of offshore developments is increasing. Offshore areas designated as highly sensitive to birds could be avoided if impact assessments are accurate (Bradbury et al., 2014). Offshore areas are essential to seabirds, seaducks, divers, grebes, and some bats. The areas are used for foraging, breed-

ing, wintering, and passage. In the U.K., 22 of their 25 breeding seabirds, along with internationally relevant seabirds, nest within areas that could be considered for wind power development. Many breeding sites are protected by the Birds Directive, so development could be stopped if significant negative impacts were identified (Bradbury et al., 2014). Due to life history features of many seabirds and some bats (long-lived, delayed sexual maturity, low fecundity), the risks of mortality, collision, avoidance, and displacement could be detrimental to populations (Bradbury et al., 2014; Johnston et al., 2014). There is currently a lack of research on the effects of offshore wind farms on bats, so this section will address bats but mainly focus on birds. Thus far, no research has revealed negative impacts toward birds or bats during the construction stage of wind farms, so only the operational stage will be considered (Bailey et al., 2014).

To begin assessing operational risks to birds from offshore wind farms, it is useful to examine the effects onshore wind farms have on birds. Sensitivity and mortality have both been observed onshore, but the level of risk has varied depending on the site, the species, and the season. This indicates that these factors could also create variation in results for offshore developments. For birds, collision with turbine blades can result in mortality. Behavioral responses such as avoidance can be energetically costly or result in habitat displacement. Birds that forage, breed, and/or migrate through developed areas should be assessed to determine the level of risk the species may incur (Bailey et al., 2014).

In a U.K. study conducted by Bradbury et al. (2014), the sensitivity of birds to offshore turbines was assessed by considering conservation and vulnerability factors for each species. The conservation factors were the species' status given by the Birds Directive, the percentage of the species' population occurring in the area for every season, the species' adult survival rate, and the species' current threat status in the U.K. Several factors were used to assess a species' vulnerability. They were the altitude of flight, maneuverability during flight, percentage of time spent flying, flying activity at night, level of disturbance from wind turbines, traffic from other sources (ships or helicopters), and the degree of habitat specialization. A system of scoring was developed for the individual factors. Species were scored for each factor and then the scores were combined so species could be ranked in terms of the risk posed to them by offshore wind farms. On a scale from very high risk to very low risk, species were ranked for the risk of collision and avoidance leading to habitat loss (Bradbury et al., 2014).

Using information gathered from the conservation factors, density maps were created for each species during each season. The density maps were combined with the risk rankings for collision and displacement to produce

sensitivity maps for every season. Using these maps, Bradbury et al. (2014) was able to gain valuable insights like waters in the northeast being extremely sensitive for large gulls and auks during the summer months. In the winter months, the Wash and inner Thames Estuary are very sensitive areas due to large gulls, common scoters, and red-throated divers (Bradbury et al., 2014). These are only a couple of examples of the information that can be gained from comprehensive sensitivity maps. Although this study only included waters in the U.K., the methods used could easily be applied to other sites to aid in creating impact assessments and in avoiding development in the most sensitive areas. Studies that determine overall sensitivity are significant, but it is also important to recognize the individual issues which contribute to collision and mortality, avoidance, and displacement in relation to birds and offshore wind turbines.

The collision of birds with wind turbine blades is one of the main concerns when planning offshore developments. Collision can result in mortality, and the effects of mortality on species with declining or unstable populations could be detrimental. Marine birds are extra sensitive to mortality since they have low productivity and are long-lived (Bailey et al., 2014; Johnston et al., 2014). Seabirds are most vulnerable to collision when wind farms are near their breeding colonies, because when breeding, the birds will frequently fly to and from their nest and foraging areas. This suggests that if wind farms are built further from shore, and therefore breeding areas, then the risk of collision would reduce; however, this hypothesis has not been tested (Bailey et al., 2014). Determining the flight height of different species is essential in estimating the proportion of birds likely to collide with turbines. Generating flight height distributions for each species makes these estimations more accurate, but individual birds will vary in flight behavior depending on the weather, method of foraging, time of day, and current activity (commuting, migrating, or foraging). For example, birds who are migrating generally fly higher than if they are commuting or foraging (Johnston et al., 2014).

Knowing the height at which birds fly in a particular area can help reduce the amount of collisions with turbines. In a study by Johnston et al. (2014), data about the bird species present and their flight heights was collected from 32 potential offshore wind farm sites across Europe. The data resulted from a variety of survey methods (i.e. boat surveys, offshore platforms, shore-based counts) but no significant difference between the methods was found. The data was combined to form continuous distributions of flight heights represented by height bands. Each of the 25 marine bird species recorded was assigned to a height band. The height bands for each site varied in order to correspond to the planned turbine designs. The percentage of the flying population in the

upper and lower risk heights and in the rotor-swept area was calculated. The estimates revealed that the amount of collisions are partially dependent on the abundance and flight behavior of a species (Johnston et al., 2014).

Different turbine designs affect the flight bands assigned to a site. Hub height and turbine diameter are two facets of turbine design which can affect how many birds collide with the blades. Models were created which varied hub height between 55 and 110 meters above sea level and varied the diameter of the rotor-swept area between 80, 90, and 126 meters. In the models, as the diameter of the blades increased, the number of turbines decreased because turbines with larger diameters generate greater outputs. When the flight height data from the proposed sites was inputted into the models, it showed that for all the species, most flights were within 20 meters of sea level. For all species, between 26% and 33% of birds were at risk of collision. These percentages varied greatly between species. When the hub height was increased, the percentage of birds at risk decreased. For most species, the percentage of potential collisions also decreased when the turbine diameter was increased. When the turbine diameter was raised from 80 to 126 meters, the percentage of birds at risk of collision on average was halved for all species. It was concluded that a useful technique in reducing the risk of collisions is to raise the hub height and use fewer turbines with larger diameters (Johnston et al., 2014). Raising the hub height and increasing the diameter also increases the energy yield from the turbines, making this technique beneficial to the conservation of energy and birds (Hastik et al., 2016).

Although there is a lack of research on bats in relation to avoidance and displacement, Sjollema, Gates, Hilderbrand, and Sherwell (2014) have studied the risk of bats colliding with wind turbines. Bats exhibit low fecundity, so added mortality from wind farms has the potential to harm population levels. Bat mortality from collision with onshore wind turbines is a well-documented phenomenon. Onshore wind farms in North America have reported high bat mortality from collision and barotrauma. Barotrauma takes place when bats are exposed to a quick pressure change near turbines. This rapid change can damage bats' air-containing organs. It is believed that similar impacts may result from offshore wind farms (Sjollema et al., 2014). The first step in predicting the risks of bat collision with offshore turbines is determining which species of bats fly offshore and how far from shore they range. Bats have long been observed flying offshore. In North America, this is especially true of migratory tree bats, including the Eastern Red Bat (*Lasiurus borealis*), Hoary Bat (*Lasiurus cinereus*), and Silver-haired Bat (*Lasionycteris noctivagans*). Sjollema et al.'s study took place off the mid-Atlantic coast (between Massachusetts and North Carolina) and examined bat activity via ultrasonic detectors. Variables such as

wind speed, air temperature, and barometric pressure were considered along with nightly activity (Sjollema et al., 2014).

In the study, the maximum distance from shore that a bat was recorded was 21.9 kilmometers, but the average distance of all recordings was 8.4 kilometers from shore. There was not a correlation between the species of bat and the distance they were detected at. Out of all the identified bats, 81% were Eastern Red Bats and Hoary Bats. Previous studies have identified bats crossing open water to reach seasonal habitats. Open water may also be crossed by regional migrants for migration and feeding. When wind speed increased, bat activity decreased without regard to the distance from shore. This relationship between wind speed and activity was also observed at offshore areas in Europe and on islands off the coast of Maryland and Virginia. Bat activity on the mid-Atlantic coast was not affected by air temperature or barometric pressure (Sjollema et al., 2014).

Although mortality is the focus of most bird studies, avoidance and displacement should also be carefully considered. Avoidance and displacement can be energetically costly, which can affect survival and fecundity. Few studies have investigated the avoidance behavior of birds towards wind turbines. The studies that have focused on avoidance used radar to track eider ducks and geese. In these studies, the migrating birds responded to wind turbines with significant avoidance behavior that reduced the risk of collision (Bailey et al., 2014). When collision risk models are created, avoidance rates are often included in the considerations. However, for many species these avoidance rates are based on expert judgment but not actual empirical data. To improve the collision risk models and to better understand the extent of avoidance behavior and its effects on birds, more studies need to be conducted with broad and fine-scale avoidance as the focus (Bailey et al., 2014; Johnston et al., 2014).

A concern related to avoidance, however, is displacement. If seabirds exhibit a certain level of avoidance behavior toward wind farms, then it could lead to displacement. Seabirds could be displaced from important foraging areas or habitats, possibly resulting in consequences for the individuals or the population (Bailey et al., 2014). North America's sea duck populations have significantly declined. Not all of the factors causing the decline are known, but a lack of suitable wintering habitats have contributed to the mass amounts of mortality and reduced reproduction. Sea ducks avoid collisions with turbines, but their avoidance behavior extends beyond this. Sea ducks in Europe have been shown to avoid foraging close to wind farms for at least the first three years of operation. Barrier effects might also affect sea ducks if they change migratory routes to avoid wind farms. By studying the movements and habitat selection of sea ducks, mitigation and management plans can be developed to reduce

the risks of displacement from wind farms. This can also be applied to other seabirds facing displacement and barrier effects (Loring et al., 2014).

Loring et al. (2014) conducted research on black scoters (*Melanitta americana*) off the coast of the New England continental shelf, an important area for wintering and migrating. Two wind farms are planned for this area and it is important for scientists to assess the impacts those will have on black scoter populations. One of the planned wind farms is less than 5 km from shore in a region used by black scoters for foraging. The other wind farm will be farther from shore, where it could potentially affect scoters' migration and breeding. Satellite transmitters were placed on black scoters to track their movements and habitat use (Loring et al., 2014).

The black scoters mainly used areas closer to shore. Using a model of the two planned wind farms, the wind farm less than five kilometers from shore had a high probability that it would be used by the scoters. Some black scoters are expected to be displaced by this wind farm. The tagged scoters showed weak site fidelity by using different wintering areas during the years of the experiment. If displacement from the wind farms does occur, weak site fidelity indicates that the scoters may be able to find alternative foraging and wintering areas. The wind farm planned farther from shore had a low probability of being used by black scoters. Current information suggests that sea ducks have a low risk of collision with turbines and that the energetic costs of displacement will be low; however, if the prevalence of offshore developments in wintering areas increases, then impacts on sea ducks and seabirds may develop into a concern for management. To help avoid future management concerns, marine spatial planning should use resource models to identify which habitats could be used by marine birds (Loring et al., 2014). Assessments similar to this one for black scoters would be beneficial for all species of seabirds and ducks that have the potential to be effected by increases in offshore wind farms.

Mitigation and Future Research

Unfortunately, most of the potential effects from offshore wind farms on fish, marine mammals, and birds and bats are detrimental. The extent of the harm is dependent on a number of factors relating to the area and species in question, but measures can and should be taken to reduce any harm as much as possible. As such, several suggestions have been made for how to reduce the potential effects of pile driving on fish and marine mammals. It is recommended that construction of wind farms not take place in areas used for marine mammal and fish recruitment. Migrating species should also be taken into account by carefully timing construction of wind farms to avoid these species

(Bergström et al., 2014).

During the construction stage, activities such as pile driving increase the risks to marine mammals and fish. Implementing a soft start or ramp-up method could help mitigate the risks. This involves steadily increasing the intensity of the pile driving over a period of 20 minutes or more. The prolonged start is meant to alert marine mammals and fish to give them the opportunity to evade the construction area. The effectiveness of this technique has not been empirically studied yet, but it is still a precaution that can be used (Bailey et al., 2014). Another mitigation method for pile driving is the use of marine mammal observers. They are trained divers who can visually or acoustically monitor the construction zone before pile driving begins to confirm that marine mammals and other protected species are absent. The divers monitor a zone close to the construction to reduce direct physical harm to marine mammals, but unfortunately, this zone is small in comparison to the entire zone of potential impact (Bailey et al., 2014). Although it is not currently included in mitigation plans for marine mammals, the effect of pile driving on their prey species should be taken into account. This could help reduce the chance of marine mammals experiencing secondary effects from the construction (Bailey et al., 2014).

A final way to mitigate the effects of construction is to change the method of construction entirely. All of the potential risks assessed so far have dealt with pile driving, because it is the most commonly used method of laying wind turbine foundations. Offshore wind turbines can also be based on gravity foundations or floating foundations. Gravity foundations do not require pile driving and emit low intensity noise during construction. The studies performed on gravity foundations thus far have found that fish and marine mammals may react by leaving the construction area, but often return soon after the noise ceases. Gravity foundations are seemingly better for marine mammals and most fish, but their construction results in more sediment dispersal than pile driving. High levels of sediment dispersal could harm juvenile fish and other sensitive organisms (Bergström et al., 2014). Floating wind turbines also do not require pile-driving and are currently being developed for deep water areas (less than 50 meters). Some floating turbines have already been installed in Norway, Sweden, and Portugal. Experimental versions have included a floating turbine in 220 meter-deep water and a two MW turbine connected into the power grid (Bailey et al., 2014). Most recently, the largest offshore wind farm comprised of floating turbines has been scheduled to be built off the coast of Scotland. This wind farm will utilize lithium-ion batteries to store electricity (Resurgence Trust, 2016). Although many designs for floating turbines have been proposed, further research is necessary to determine which options are

most feasible and efficient (Bailey et al., 2014).

Although the operational phase does not pose as great of a threat to marine mammals and fish as the construction stage, mitigation and management techniques can still be used to reduce the risks. Individual-based models can simulate the effects of existing and planned wind farms on a species' population. These models can be customized to the area in question to identify how to manage the population during wind farm operation (Nabe-Nielsen et al., 2014). Electromagnetic fields (EMF) are usually assessed as having low impacts on fish, but the effects can vary depending on the ecosystem. It is hypothesized that damage from EMF can be lessened by alterations to the design of the turbine cables (Bergström et al., 2014).

Several mitigation techniques and tools have also been identified for reducing the effects of offshore wind turbines on birds and bats. Thorough impact assessments should be conducted at all proposed sites during each season to identify the species present and the areas that are particularly sensitive. SeaMaST (Seabird Mapping and Sensitivity Tool) is a GIS tool that creates models of the potential risks seabirds face from planned wind farms. Researchers have also produced Species-specific Sensitivity Indices (SSIs) that assign species a level of sensitivity based on life history traits, behavior, and conservation status. SSIs have been utilized in impact assessments in Germany and the UK (Bradbury et al., 2014).

It is recommended that developers avoid areas that are significant for conservation or are especially sensitive. After recognizing which seasons are most important for species, construction and maintenance should be timed to avoid these periods (Bailey et al., 2014). Wind farm developers should also consider the turbine design. It has been shown that by raising the hub height and increasing the diameters of turbines, fewer are needed and the risk of birds colliding with the blades is reduced. However, migrating seabirds fly at higher altitudes, so if this technique is used, these birds need to be considered in the mitigation plan (Johnston et al., 2014). Collision is one of the main concerns with birds and wind turbines. Assessments of collision risks rely on data about the flight heights of seabirds, but every method of collecting this data has pros and cons. Mitigation may include using various methods of data collection to increase the accuracy of impact assessments. Some of the methods include visual observations, tagging, high-definition imagery, and radar (Johnston et al., 2014).

Possible mitigation techniques for bats include monitoring migratory and seasonal activity, building wind farms farther from shore, and adjusting the turbine cut-in speed. Onshore developers have utilized acoustic monitoring during pre-construction phases to gather data about migrating bats. This

could easily be applied to offshore wind developments as well. Bat activity also fluctuates seasonally and could be monitored in a similar way. Understanding when migratory and seasonal activity are at their peak could assist in management efforts (Sjollema et al., 2014). It was hypothesized that wind farms built farther than the maximum detection distance from shore would be unlikely to impact bats. More research is necessary to test this postulate because the study by Sjollema et al. (2014) only detected bats flying at lower levels, and it is possible that bats may be flying at higher heights at greater distances from shore. If the hypothesis is correct, then this is a positive sign for bats since most proposed sites for wind farms are at or past the maximum distance of 21.9 kilometers. Adjusting the turbine cut-in speed could also reduce collisions. The cut-in speed is the speed that wind must reach before the turbine will begin rotating. Onshore wind farms have found that by increasing the cut-in speed at night from 5.0 to 6.5 meters per second, bat mortalities were decreased by 44% to 93% (Sjollema et al., 2014). Implementing a faster cut-in speed at night for offshore wind turbines could result in similar mortality reductions.

It is important for developers and regulators to implement mitigation techniques whenever possible; however, these techniques are expected to change over time as our knowledge about the impacts of offshore wind technology expands. Knowledge gaps remain about many aspects relating to offshore wind power. The lack of some information is due to offshore wind power being a relatively new technology. Future research should focus on gaining more information about the species under current investigation as well as studying new species and their responses to offshore wind farms. There is also a limited understanding of the cumulative impacts from offshore wind farms in conjunction with other disturbances such as vessel traffic. As a result of the novelty of offshore wind farms, current research has only addressed short-term impacts on marine and terrestrial species (Bergström et al., 2014). As time continues, long-term studies should be conducted on the effects of wind farms on food webs, ecosystems, and regional populations.

For the present, offshore wind developers and researchers should conduct thorough impact assessments before beginning construction. Multiple mitigation techniques should be used during construction and possibly operation to reduce the negative effects wind turbines might have on a range of organisms. The goal of this literature review is to aid in the process of mitigation by examining all of the available options for a variety of organisms instead of a single species, as in most studies. This review also prompts further research by clearly identifying knowledge gaps that need to be filled before construction of more offshore wind farms occurs. By adopting these techniques and continuing research, offshore wind power can become a form of alternative energy that is

positive for marine and terrestrial environments and the myriad of organisms which inhabit them.

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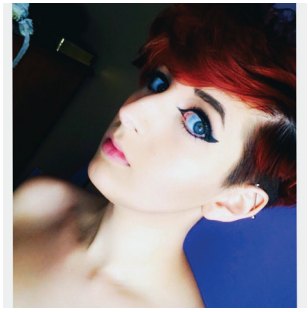
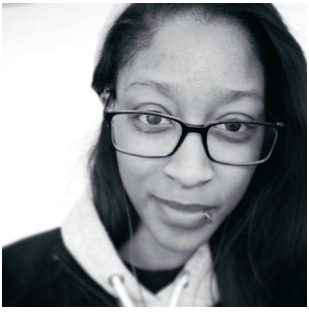
About the Authors

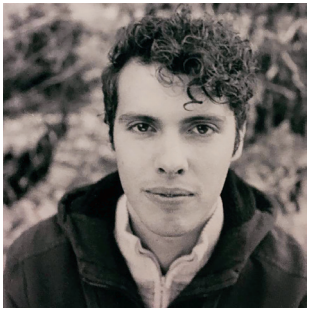
Tawn Dickison is now a first-year graduate student at Missouri State University pursuing a degree in Master of Fine Arts. After she receives her degree, she would like to teach art foundation courses at a university.



Sydney Gunter is a lab assistant at the Computer Services Help Desk, and she enjoys working with people of all walks of life with computer problems as well as emotional issues. She is a Computer Information Systems and ITSM double-major, and she hopes to have a career much like the part-time job she has now in her future.



Janeshae Henderson is a Missouri State University alumni. She graduated in Spring 2016 with a BFA in Photography. She is considering furthering her education and pursuing film production and maybe even business. Her goal is to eventually move to California and become a successful photographer.



Cory Powell is a senior at Missouri State University pursuing a degree in Art with an emphasis in Photography. He plans to be a practicing artist and either start his own photography studio or become an art professor.

Shannon Wick is a senior at Missouri State University majoring in Professional Writing with minors in both Creative Writing and Art. She has worked with *LOGOS* since 2014 and is currently the chief editor. She plans to attend graduate school next year and hopes to join the Peace Corps after her education.

Christina Woods majored in Illustration and minored in Spanish. Outside of continuing to be a devoted nerd, her goals are to be happy and to work for Disney, Marvel, LucasFilm, or Pixar in the future.

Caleb Marshall is a first-year Psychology major who is interested in ethnic and sexual minority research in the fields of both psychology and language. He plans on studying Quantitative Psychology after graduating from Missouri State, and he hopes to pursue a career in Academia and Research Psychology. Also, he's interested in single-origin coffee, dogs, and obscure classical music—the stranger the better!

Dr. Erin Buchanan is an Associate Professor in the Psychology Department at Missouri State University. She graduated from Texas Tech University with her PhD in 2008, and she currently teaches at both the undergraduate and graduate levels. Her academic interests include the meaning and use of language, memory, and statistics.

Mary Kranick graduated Summa Cum Laude from Missouri State in December of 2015 with a degree in Exercise and Movement Science and is an ACSM certified exercise physiologist. She will be entering the University of Kansas's doctoral physical therapy program beginning June of 2016. Meanwhile, she is working full time as a phlebotomist.

Zachary J.M. Beck graduated Summa Cum Laude from the Honors College with distinction in History from Missouri State University in May 2016 and is currently pursuing a Master of Arts in Religious Studies at Missouri State. He is interested in New Testament studies and the influence of religion—particularly Christianity—on the Western world.

Josh Gooch is a sophomore at Missouri State University pursuing a degree in Physics and Math. After completing his education, Josh plans to apply his skills to the financial sector working as an actuary or quantitative analyst.

Elizabeth Wood is a recent graduate of Missouri State University with a degree in Biology and a minor in Chemistry. She plans to either become a nurse or obtain a job in the conservation field. She dedicates her publication to her loving mother, Kimberly Wood.

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