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Welcome

Zeph Schafer*

Welcome to the fifth installment of the *Oregon Undergraduate Research Journal*! This issue marks the second anniversary of our first publication. Students started this journal to honor and encourage research beyond the "term-by-term grind" of classes. Now, for two years *OURJ* has continued to publish undergraduate research in order to share outstanding work with the university community and to provide inspiration for student peers.

In this issue, we are excited to publish four articles in the disciplines of Economics, Environmental Science, English and Biology. In "Apartment Price Models for the Glenwood Riverfront Development," Joseph Friedman employs Hedonic price modeling to assess student-housing prices near the University of Oregon. His research presents recommendations for developers and governments involved in a proposed development in nearby Springfield. In "Prey Detection and Feeding Success of the Comb Jellyfish *Mnemiopsis leiydi* on Copepods in Still and Turbulent Waters," Clare Chisholm investigates the effects of water turbulence on the feeding behavior of the *M. leiydi* jellyfish. Chelsea Arsenault's "The Virgin Knight: Spenser's Embodiment of Duality in Elizabethan England" investigates gender dynamics within the poetry of sixteenth-century English author Edmund Spenser. Finally, in "Bioremediation Mariculture in Zanzibar, Tanzania: A viability assessment of using bath sponge and pearly oyster farms to filter highly polluted waters in the Zanzibar Channel," Hayley Oakland investigates the ability of marine organisms to self-restore their environment after pollution.

The publication of this journal depends on the support of many dedicated individuals. Our editorial board, Charlotte, Lauren, Mari, Sage, Laura, Janelle, Jessica and Biraj devote their time throughout the year to finding and publishing high-quality research. I greatly appreciate their commitment. Our faculty advisors, Dr. Barbara Jenkins and Dr. Kevin Hatfield, provide invaluable advice and guidance on the development of the journal. Finally, this issue would not have been published without the technical support provided by the University of Oregon Libraries, and especially John Russell and Cat Bradley. Thank you!

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Editorial: Expanding Opportunities for Research

Deb Carver, Philip H. Knight Dean of Librarians

I've been fortunate to attend several excellent universities as an undergraduate and as a graduate student. As an undergraduate, I had plenty of opportunities to write the classic "term paper." The process taught me a lot about organizing my thoughts, finding relevant information, and reaching conclusions that were backed up by the evidence. But I do not remember feeling challenged. I was systematically collecting the facts and opinions from others, and putting them into my own words. Needless to say, my papers were saturated with citations and footnotes. But, I wasn't adding anything to the scholarship of my discipline.

I have noticed one profound and very positive change since my undergraduate years. Undergraduate research has become a core focus across the disciplines. This change has occurred at many of the research universities across the country--including the University of Oregon. In the sciences, that research often occurs in the lab. Increasingly, scientific investigation takes place online using high performance computing capabilities. In the social sciences, some of that research takes place in the field. In the humanities, undergraduate research often happens in the library. Not with the secondary sources that I used as an undergraduate student, but with primary sources such as manuscripts, archives, rare books and government documents.

When I was a student, these 'special collections' were sometimes off limits to undergraduates. The manuscript reading rooms were filled with only the most seasoned scholars, breathing rarified air, carefully reviewing a file folder with white gloves. Not the most welcoming place on campus for the typical student. Thankfully, most research libraries now actively encourage undergraduates to use the collections and discover the intellectual challenges associated with original research. New theories, interpretations and discoveries can happen at any time during one's academic career. The thrill of saying something that no one has said before can be transformative. I do not know this for certain, but I suspect that those students who have the opportunity--and the support--to engage in original research, go on to become active lifelong learners.

Today, the Special Collections reading room at the University of Oregon is one of the busiest places in the library. Students take a break from the computer and the smart phone to engage with the past. They ask lots of questions. They're curious about their cultural history. They see a rich and diverse resource ready for exploration. They begin to see themselves as scholars. (White gloves are no longer required). This is what a research university is all about.

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Artist Statement: "Dragonfly Halo"

Sage Cruser*, Department of English

I usually prefer to photograph with a high-quality camera of some sort, but I snapped this photo with my phone. It was all I had available when the moment came along, and I wasn't going to fiddle around looking for another camera; the moment was fleeting.

I captured this photo while sitting at my table one morning, a nearly empty white coffee mug to my right. The morning light had just started to creep in through the patio doors, and with it came a strikingly blue damselfly (like a dragonfly, just smaller). The damselfly flew right into the coffee mug and landed on the bottom, surrounded by a shallow ring of the remaining coffee. I managed to grab my phone and snap this picture, right before the visitor flew away. This is one of my favorite photos I have taken because it is both beautiful and unexpected; it makes me think. The sharpness, position and color of the damselfly starkly juxtapose with the perfectly circular and soft ring of coffee, while still managing to compliment it. I also realize that I will never again get a shot exactly like this one, which makes it all the more special to me.

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Apartment Price Models for the Glenwood Riverfront Development

Joseph Friedman, Economics

ABSTRACT

This study examines the rent prices of the student housing apartment market surrounding the University of Oregon. The first key component of this study includes a Hedonic price model that helps evaluate what apartment complex amenities and characteristics are most important and influential in determining rental rates in the local community. Secondly, using the information from our Hedonic price model, this study will help the city of Springfield in their plans to develop a student housing project in the Glenwood Riverfront district, located along the Willamette River. Specifically, this study of rental prices and apartment complex attributes should be useful in evaluating a potential student housing project to ensure sufficient rental profit for developers and for tax revenues for Springfield under their current development budget constraints.

INTRODUCTION

In 1998, the city of Springfield annexed the Glenwood district along Franklin Boulevard from Eugene. The Glenwood Riverfront area is a one square mile region located between Eugene and Springfield along the Willamette River. Since gaining jurisdiction, the city of Springfield has targeted the Glenwood Riverfront area as prime location for development which could potentially improve the local Springfield economy. Specifically, the greater goal of the Sustainable Cities Initiative of Springfield is to develop the Glenwood Riverfront area in order to create Nodal or mixed-use developments that create a neighborhood-like environment in this region. Mixed-use developments are defined as buildings and developments that have multiple purposes including commercial, residential, employment and transit infrastructure. However, with the constraints of Springfield's budget along with the lack of developer interest, the city has thus far been unable to jumpstart their mixed-use development plans.

In the long term, the city envisions the Glenwood area to include business offices, low-income housing, and commercial properties. However, for the scope of this project, we will focus on the potential impact of incorporating student-housing apartments into the Glenwood Riverfront development. Given the increased enrollment at the University of Oregon and the

success of other recent student housing developments such as the Courtside Apartments, we foresee the potential of a student housing project as a key component in the greater Glenwood Riverfront development. The question at hand will be to what extent can the impact of a student housing development be measured and subsequently translated to developers in order to induce a development in the Glenwood Riverfront area. While we will discuss the specifics of our research approach later, the first step in our study will be to examine what components of housing developments in the local community are most important in determining rental rates for tenants. In evaluating this problem, we hope that our results are applicable towards determining cause and effect of other important questions for Springfield. A study of rental prices and apartment complex attributes should be useful in evaluating a potential student housing project to ensure sufficient rental profit for developers and for tax revenues for Springfield under their current development budget constraints. Targeting which apartment amenities are most influential on rental prices in the local community will allow us, and more importantly the city of Springfield, to market a student housing development as a beneficial project for developers and the city as a whole.

BACKGROUND

University of Oregon Housing Developments

According to the University of Oregon's enrollment history data, over the last five years the university has seen undergraduate enrollment increase from 16,681 in 2007 to 20,631 in the fall of 2011. As enrollment continues to increase, the amount of local student housing developments must continue to increase commensurately, in order to keep pace with this prolific demand. While specific characteristics of the apartments are unique for each development, a majority of the newer developments are designed with modern characteristics and tend to include more amenities such as a washer/dryer, high speed wireless internet, covered parking, and several others. Consequently, the new student housing complexes located near campus have higher rental rates than local houses or older apartments with monthly rates ranging between $400-800 per person. Our goal will be to identify and analyze the various amenities that are included in local student housing complexes in an effort to see their effects on rental rates. In order to analyze the effects on rent that the various housing amenities have, we collected student rental rates from the largest rental agencies in the Eugene area. These agencies include Mallard Properties, Bell Real Estate, Von Klein Property Management, Eugene Rentals. In addition, we retrieved rental information from some of the larger independent student housing complexes such as Duck Village and the Courtside/Skybox apartments. Our objective in collecting data was to acquire as much diversity as possible so that our coefficients predicted by the model would be as close to their true values as possible. The more comprehensive and explanatory our study is, the more helpful it will be to the city of Springfield in the future as they attempt to market this proposed project to potential investors and developers. Ultimately we hope to develop an accurate model that describes the relevant attributes, construction costs and proportional rent for a student housing complex in the Glenwood area looking to compete in the evolving U of O

student housing market. We hope this model, at minimum, will provide insight into the benefits and costs to be considered in any such development in the Glenwood area.

LITERATURE REVIEW

The goal of our project is to construct a hedonic model that will allow us to determine the feasibility of a student housing complex in the Glenwood Riverfront area of Springfield. To do so we need to gather data on observable characteristics of rental price determinants, and estimates of the construction costs, preferably value added cost estimates associated with each amenity specified in the model. In order to familiarize ourselves with common attributes of hedonic rental models, we did some research on existing studies. Many of these studies helped to fortify our hypothesis of the most significant variables, and the likely sign of their coefficient in relation to our dependent variable.

For the scope of our project, we wanted to investigate previous studies that dealt with similar hedonic price models. Specifically, we identified previous research that focused on hedonic models aimed at identifying rental rate characteristics using similar variables to those used in our study. While we were fortunate enough to find extensive relative research, we decided to focus on a limited quantity that we found to be most pertinent to our specific research on the University of Oregon student apartment market.

As a starting point, we reviewed a previous study conducted by University of Oregon students in 2006, that uses a similar model to ours in an effort to "examine the rent prices of apartments and sale prices of condominiums in Eugene, Oregon." From the substantive Brown, Reiter, and Pietzold (2006) findings, we were able to outline a feasible plan for how to best conduct our own research. For example, their study discusses the difficulty that exists in the Eugene area with obtaining rental pricing information. The major rental agencies in the Eugene area, Mallard Properties, Bell Real Estate, Property Management Concepts, and Von Klein Property Management, manage a vast majority of the student housing complexes surrounding the University of Oregon campus. With this in mind, as the 2006 study indicates, if one of the major management companies is unwilling to provide the necessary data to conduct a thorough hedonic price model, it significantly limits the amount of observations one can obtain as well as leaves room for biased results. In reviewing Brown, Reiter, and Pietzold (2006), we found that Bell Real Estate was unwilling to release the needed information to the students in their research process. Understanding that cooperation from and collaboration with Bell Real Estate would likely be difficult, we decided to focus on reaching out to them in order to give ourselves ample time to obtain their rental pricing information. While in the end we were unable to obtain significant data from Bell Real Estate, we were able to establish communication with one of their managers and were restricted more by time restraints than by Bell's unwillingness to share the information.

Another key element of Brown, Reiter, and Pietzold (2006) that helped in outlining our research process was to identify the variables they used in their study. While a majority of the included variables were obvious for our hedonic price model, such as square footage, number of

bathrooms/bedrooms, washer/dryer included or not, etc, others were somewhat more abstract but nevertheless significant in predicting power. For example, while we had planned to include some type of variable to measure an apartment complexes distance to campus, by observing the significance of the "travel time to campus" measured as UO time in the study(a roughly $4 decrease in price for every minute increase in time), we decided it was crucial to include a time variable in addition to a simple distance variable. We also believe that because over the last 6 years there has been a significant increase in large student housing complexes in the surrounding Eugene area, the landscape of the University of Oregon housing community has broadened and now expands beyond the West Campus neighborhood much more than it did in 2006. With this in mind, a time variable to a specific location may be more predictive than a distance to campus variable that may not capture the significance of a complex built in a different neighborhood around campus such as the newly built Skybox and Courtside Apartments built in the new Arena District of campus. In addition, because the west campus neighborhood is so densely populated with complexes, we believe that a time variable that measures walking time will allow for more variation than a basic distance calculation. For example, a two block distance between two complexes may only record as a 0.1 mile difference in distance to campus, but up to 7 or 8 minutes difference in walking distance to campus. Based on the 2006 study, we believe this time disparity is a critical element in determining rental rates. However, as we will explain later, the strong multicollinearity between time and distance to campus forced us to ultimately take out our time to campus variable to strength our overall regression results. Nevertheless, for the purpose of our investigation, it was beneficial to have Brown (2006) as a basic outline to help frame our regression model.

In evaluating the results of Brown (2006), we analyzed the findings of their apartment rental rates without delving too much into the condominium side of their research. While the 2006 study concedes error in calculation with their condominium results, overall the apartment rental rate model appears to be a fair representative of the student housing apartment industry in Eugene. Aside from a lack of explanation as to the randomization process Brown (2006) used while acquiring their data, the analysis produced results that appeared unbiased and fairly consistent with expectations. The explanatory variables used by Brown (2006) include square footage(sqtfi), number of bathrooms(bathi), deposit amount (depositi), time to campus(uotimei), washer and dryer included in the unit (dwduniti), cleaning deposit fee clearningi), and bike storage (dbikestoragei). In using these variables, their final regression included the following:

$$Rent(i)= \beta 0 + \beta 1sqfti + \beta 2bathi + \beta 3depositi + \beta 4uotimei + \beta 5dwduniti+ \beta 6dpetsi +\beta 7cleaningi + \beta 8dbikestoragei$$

Where:

$\beta 0$: 361.667 $\beta 1$: 0.343 $\beta 2$: 55.627 $\beta 3$: -0.206 $\beta 4$: -9.877 $\beta 5$: 80.149 $\beta 6$: 41.135 $\beta 7$: 0.155 $\beta 8$: 24.603

This model demonstrates a linear regression model, similar to the one we will look to use in our investigation. In its most basic form, we can view this model as $Y_{i=}\beta x + E_{i,}$ where β represents the coefficient vector for any particular model and x represents the discovered values of any variable included in the model.

From their results, we can see the predictive qualities that one may expect to see from the above variables as they relate to rental rates in the Eugene Area. Additional square footage, bathrooms, bike storage, and number of units in the complex all appear to positively and significantly effect rental rates, while time to campus and amount of deposit appear to have a negative effect. While our evidence does not lead us to believe that deposit increases should lead to decreases in rental rates as the 2006 study suggest, overall this model provides a starting point to base our results off of. Essentially, we foresee our study being an updated rendition of the 2006 study with changes coming from the dynamic and continual evolving Eugene student housing community. With a significant increase in newer and larger student housing developments over the last 6 years, certain variables may be more or less significant as the scarcity of certain amenities has decreased.

In taking a step back from analysis of the Eugene student housing market, *The Effect of Rent Control on the Price of Rental Housing: An Hedonic Approach ,* or Marks (1984), provides one of the first hedonic price models used to research rental rates. This study was conducted at the University of Wisconsin, in an investigation into the effects of rent control in urban housing markets. Specifically, this study used data from the city of Vancouver to research "the extent, at the margin, to which controlled rent falls below the level it would reach if the particular unit were not controlled." While the intent behind our research will not be the same as Marks', there are still key elements of his study that will benefit us going forward. For example, the hedonic price model Marks uses in his study will be a good reference point for our study in terms of what variable to incorporate and what correlations we expect these variables to include. Perhaps the biggest limitation of this study will be that it was conducted over 25 years ago. With this in mind, we anticipate several additional variables will need to be included in our price model to accommodate current advancements in technology and design. Examples of this will be discussed further in the methodology section.

In a subsequent study conducted in 1989, *Determining Apartment Rent: The Value of Amenities, Services and External Factors,* Sirmans, and Benjamin provided a report published in The Journal of Real Estate Research that broadened the application of the hedonic price model as it relates to rental rates. The primary goal of this study was to investigate a similar concept to what we are researching for our project: what are the effects of various amenities on the rental rates for housing? While this study focuses on multifamily housing and ours student housing, we expect the overall findings to be similar to what we will discover in our research. For example, the authors of this study found that covered parking and "modern kitchen" were both independent variables that had a great impact on rental rates, which we assume will also be evident when we conduct our study. Similarly to Marks (1984), this study also provides a useful hedonic model that will help in setting up our own model with various independent variables. One key component of this study that should prove beneficial for us moving forward is the use of

external factors being considered in the experiment. By including variables such as traffic congestions and access to public transportation, this study, and consequently our study, will be able to more accurately monitor the true effects of the various independent variables on the rental rate. As mentioned for Marks (1984), this study is somewhat limited as it was conducted 20 years ago and several variables that will be crucial to our investigation may not have been relevant or existent when the study was conducted.

Most other existing literature we researched which attempts to model student rental prices specifically cite variables distance to campus, number of bedrooms/bathrooms, utilities included, as well as a basic list of amenities (dishwasher, washer/dryer, parking, balcony or outdoor space, common space, exercise room, security etc. etc.) as the most significant factors affecting rent per square foot in the student market. We have been fortunate enough to gather data on many of the relevant variables that other parallel studies have found significant in their regressions. Des Rosiers and Theriault are among the more prominent researchers to successfully use hedonic models that accurately describe cause and effect relationships. Their report in the journal of real estate studies entitled *Rental Amenities and the Stability of Hedonic Prices: A Comparative Analysis of five Market Segments*, used a less conventional experimental design and hypotheses to yield some interesting results. One segment analyzed in their five market comparison was the student housing market at a university in Quebec Canada. They postulated that there were three main factors which contribute to student rental prices there. The first being amenities, services and physical characteristics, encompassed in our model by variables such as number of bedrooms, bathrooms and a myriad of dummy variables such as dishwasher, balcony, hardwood floors etc. The second characteristic was locational attributes, addressed in our model by variables distance to campus, distance to commercial grocery development and distance to nearest bus line. The final factor they hypothesized about was the effect of vacancies on rent. We did not include this variable in our model, because it quickly became apparent to us, as it did to Rosiers and Theriault that "a market dominated by the presence of a major university consequently displays a relatively low price-elasticity of demand for rental services," suggesting that markets remain highly specific and that vacancy rates are not a significant factor in determining rent around universities, because students are fairly insensitive to price changes. This conclusion not only nullifies vacancy rates as a potentially omitted explanatory variable, but it makes an assertive statement about the prolific demand for student housing around campuses. It was easy for us to find evidence of similar conditions of disequilibrium between supply and demand around the University of Oregon campus as well, which only serves to reinforce the potential usefulness of our model in assessing the Eugene/Springfield market. Des Rosiers and Theriaults' study found distance to be the strongest variable in determining rent. They concluded that, "the rent premium assigned by the market within a 500-meter radius from the University represented roughly 16.5% of average monthly rent, as opposed to 3% and 1.7% for the second and third 500-meter belts respectively." In accordance with this conclusion, they posited that "a central location within walking distance of the university may drive landlords to increase rents throughout the academic year in order to compensate for higher vacancies during the summer time." These two conclusions only reiterate findings of inelastic rental demand found around most college campuses.

A comparative 1987 study conducted at the University of Alabama by Economics and Real Estate professors Karl Guntermann and Stefan Norrbin entitled *Explaining the Variability of Apartment Rents,* used a similar model to investigate rents surrounding college campuses. They concluded that "common area amenities and extra bedrooms for a given apartment unit size have a significant affect on rent. While students may have a strong location preference for the area around a university, they are sensitive to the condition of apartment units, with better quality units having significantly higher rents." If the results from both of these studies hold true for our model, it will suggest that although students are fairly insensitive to price changes in close proximity to campus, contrary to popular belief, students are sensitive to the condition of apartment units.

The permanent income theory states that people will spend money consistent with their expected long-term average income. As concluded in Jonathan Ogur's paper *Higher education and Housing: The Impact of Colleges and Universities on Local Rental Housing Markets*, "college and university students have high permanent incomes in relation to the rest of the population. More-over, among all groups in the population, college and university students are especially likely to be affected by permanent income in their consumption of rental housing services." Pg 388. This would help to explain the insensitivity to movements in price in units close to campus, and the preference and willingness to pay for higher quality units due to their higher expected long-term incomes.

LITERATURE REVIEW

In order to determine the feasibility of a student housing project in the Glenwood riverfront area, we decided that using a hedonic property model to gather observations on the attributes that comprise a typical unit would best allow us to speculate on what a structure might look like if built in this area. Thus our original model included the following variables:

# of bedrooms	Years since built	DUMMY internet included
# of bathrooms	# of renovations	DUMMY parking
Average deposit	# of floors	DUMMY sustainable design
# of additional units	DUMMY balcony	DUMMY sustainable certification
Distance to campus	DUMMY bike storage	DUMMY Utilities
Distance to EmX line	DUMMY complex security	DUMMY washer/dryer included

Distance to grocery store	DUMMY dishwasher
Time to walk from campus	DUMMY exercise room

Through a combination of site-specific internet research, relevant literature review and consultation with management companies, we were able to define these variables to be the most relevant and accessible in determining rent per square foot in the Eugene market. For variables such as number of bedrooms, bathrooms, number of floors, average deposit, number of additional units, years since built, and number of renovations, we simply collected the appropriate quantitative values for each variable. For our distance variables, we used Google maps to approximate the distance to campus, grocery store and EmX transit bus stations from each of the observations in our study.

In measuring the "distance to campus" we observed the distance from each housing complex to a specific "East 13th Avenue" address on Google Maps. We chose to use this specific location on campus because it closest in proximity to a majority of classes as well as encompassed the many other attractions on 13th that are near the actual university campus such as the U of O book store and several local restaurants and bars which cater to college students.

For the "distance to grocery store" variable, we calculated the distance from each observation in our study to either the Safeway on 18th avenue or the Market of Choice on Franklin Boulevard, ultimately recording the lesser of the two distances. We chose these two establishments because they are the two largest grocery stores in the geographic region surrounding the vast majority of student housing complexes in the campus district of the university. While we acknowledge that there are smaller markets and convenience stores that may be closer in proximity to some student housing complexes, the extent to which students can purchase groceries beyond the basic necessities is quite limited.

In measuring "distance to EmX" we calculated the distance between each complex and the closest EmX station that runs along Franklin Boulevard. For example, the "distance to EmX" for a student housing unit on 14th and Patterson would be the distance between the unit and the EmX Hilyard Station, the nearest location that a resident could actually get on the EmX line.

Lastly, our "time to walk to campus" variable was calculated using Google maps to approximate the time it would take for an average student to walk to campus, specifically, the time it would take to walk to the campus entrance on 13th Avenue.

In addition to the hedonic property model which is useful to evaluate general physical, mostly non-financial characteristics of property rents, we will obtain estimates of the construction costs associated with building a development to a particular set of standards. We hope to obtain estimates of the value added per amenity costs of each characteristic we would expect to observe in a new complex in the Glenwood area.

Through reconciliation of these two figures, we have a rough sketch of appropriate rent to charge to cover total construction costs, as well as the derivative rent associated with each observed amenity. Although we understand these estimates will be far from perfect, we hope it will provide a framework, and a snapshot for parties on both sides of the equation, i.e. the city of Springfield, who is trying to incentivize development in the Glenwood area, and developers/management companies who are looking to expand their property ownership and differentiate themselves within the marketplace.

HEDONIC PRICE MODEL RESULTS

Initially, we conducted our investigation with "rent per square foot" as our dependent variable. However, our first regressions produced some unperceived results most notably unrealistic coefficient signs and values, likely due to specification issues in the model. With rent per square foot as our dependent variable, we obtained a relatively modest R-squared value of .518 with only 5 explanatory variables being significant in our regression model. [1] Upon observing our regression output, we revised our final hedonic price model to have our dependent variable be simply "rent" with "square footage" becoming an explanatory independent variable in the model. Our final regression appears as the following:

$$Rent_i = \beta_0 + \beta_1 bathrooms_i + \beta_2 bedrooms_i + \beta_3 deposit_i + \beta_4 distancetocampus_i + \beta_5 distancetogrocery_i + \beta_6 DUM\_bikestorage_i + \beta_7 DUM\_dishwasher_i + \beta_8 DUM\_exercise_i + \beta_9 DUM\_furnished_i + \beta_{10} DUM\_internet_i + \beta_{11} DUM\_security_i + \beta_{12} DUM\_utilities_i + \beta_{13} floors_i + \beta_{14} renovations_i + \beta_{15} sqft_i + \beta_{16} additionalunits_i + \beta_{17} distancetoEmX_i + \beta_{18} DUM\_balcony_i + \beta_{19} DUM\_sustainablecert_i + \beta_{20} DUM\_washerdryer_i + \beta_{21} yrssincebuilt_i$$

In the above regression, β_0 represents our constant value while β_1 through β_{21} represent the coefficients for each of our respective dependent variables. These coefficients represent the value that each variable in our model has on the rent value ($) holding the rest of variables in the model constant. For example, if hypothetically β_1 had a value of 100, we would expect a one unit increase in "bathrooms" to result in a $100 increase in rent.[2]

After finalizing our regression model based on the variables we had obtained information on during our data collection, our investigation produced the following regression outputs:

[1] Appendix A
[2] Appendix B

Dependent Variable: RENT
Method: Least Squares
Date: 05/31/12 Time: 14:12
Sample: 1 134
Included observations: 134
White Heteroskedasticity-Consistent Standard Errors & Covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	251.9520	179.1823	1.406121	0.1625
BATHROOMS	83.81231	44.19789	1.896297	0.0605
BEDROOMS	139.3712	57.97780	2.403871	0.0179
DEPOSIT	0.593993	0.114016	5.209729	0.0000
DISTANCETOCAMPUS	-277.0824	71.06340	-3.899086	0.0002
DISTANCETOGROCERY	-101.2438	50.74576	-1.995119	0.0485
DUM_BIKESTORAGE	82.06390	28.02294	2.928455	0.0041
DUM_DISHWASHER	-89.39012	64.19573	-1.392462	0.1665
DUM_EXERCISE	-338.8507	145.1100	-2.335130	0.0213
DUM_FURNISHED	733.8645	193.6986	3.788693	0.0002
DUM_INTERNET	237.3088	167.4603	1.417105	0.1592
DUM_SECURITY	101.6929	43.41792	2.342187	0.0209
DUM_UTILITIES	117.5668	132.5530	0.886942	0.3770
FLOORS	-45.79934	21.94388	-2.087112	0.0391
RENOVATIONS	83.19379	73.23183	1.136033	0.2584
SQFT	0.321179	0.162490	1.976600	0.0505
ADDITIONALUNITS	-0.824369	1.474486	-0.559089	0.5772
DISTANCETOEMX	1.924736	66.68903	0.028861	0.9770
DUM_BALCONY	7.847911	24.40578	0.321560	0.7484
DUM_SUSTAINABLECERT	15.83493	48.31324	0.327756	0.7437
DUM_WASHERDRYER	39.69828	45.24383	0.877430	0.3821
YRSSINCEBUILT	-2.099652	3.410551	-0.615634	0.5394

R-squared	0.964751	Mean dependent var	1910.522
Adjusted R-squared	0.958142	S.D. dependent var	697.6829
S.E. of regression	142.7400	Akaike info criterion	12.90894
Sum squared resid	2281967.	Schwarz criterion	13.38471
Log likelihood	-842.8992	Hannan-Quinn criter.	13.10228
F-statistic	145.9730	Durbin-Watson stat	1.552346
Prob(F-statistic)	0.000000		

EVALUATION OF FULL REGRESSION OUTPUT

Despite the fact that a number of our variables were insignificant, we decided to leave them in the model in order to exemplify the full list variables we collected data upon which we had originally hypothesized would have significance in determining rent. However, after running a correlation matrix between all of our variables, we removed the variables time from campus because of its perfect correlation with distance to campus, as well sustainable design because of its high correlation with sustainable certification. Highly correlated independent variables cause multicollinearity, which occurs when there exists a linear relationship between two variables, meaning that when collinear variables are included in a model, each unique variable that is

collinear give us inaccurate information regarding their relationship to the dependent variable, because some of their unique explanatory power is being shouldered by another variable or vis-versa. Although multicollinearity does not cause bias or inconsistency, it does cause variances and standard errors to be higher, and thus t-statistics to be smaller. Another issue with our data was heteroskedasticity, this is a problem with most cross sectional data such as ours. It occurs when the disturbance term in each observation is not constant and results in coefficient estimates that are inefficient. Because we did not know what the form of our heteroskedasticity might look like, we used White's correction because it does not require a form to be specified. White's correction is an automated correction in eviews that corrects the standards errors to normalize the output. Additionally, because there was no variation in the data for dummy variable parking(it was observed in every circumstance), we could not analyze its effects on rent, so we removed it from our model.

The R-squared value of our new regression was .964 which tells us that roughly 97% of the variation in rent is caused by the explanatory variables in our model. This is a high R squared value, it suggests that we have included the most important explanatory variables in determining rent.

APPLICATION OF THE MODEL

In order to determine the feasibility of a student housing project in the Glenwood riverfront area, we gathered information on an estimate of the cost structure that might face a student complex to be built in the Glenwood area. We were able to use the cost structure of an existing student complex as a proxy for the prospective development in Glenwood. After we provided Anslow & DeGeneault construction with an estimate of the cost of land at the proposed building site for the Glenwood development, our contact was able to factor this land cost into his existing cost structure. In doing so he was able to inform us that a 44,000 Sqft (not including an underground parking lot), 34 unit apartment complex would cost around 5.3 million including between $150-$200,000 in interest payments for construction financing, as well as $50,000 in permanent financing costs. These figures assume a loan for 75% of the total costs of the project.

Once we had these numbers we used the variables of significance from our full model(5% significance level) in order to determine an auxiliary regression specific to the Glenwood area. We left out the dummy variables furnished and exercise room, even though they were both significant in our full model. By looking at trends in our data, we deduced that only complexes with more than 80 units had an exercise room, and only one apartment complex had fully furnished rooms available so neither of these were relevant to our perceived structural design. Given these constraints, our model for the Glenwood Riverfront complex looked of the following form:

Rent = β1 + β2(Bathrooms) + β3(Bedrooms) + β4(deposit) + β5(security)+ β6(floors) +β6(SqFt.) β7(BikeStorage) + β8(Distancetocampus) + β9(Distancetogrocery) [3]

We decided to run two different regressions in order to see how our model would compensate for price discrimination between differing units, also because price discrimination is a better assumption when we are attempting to simulate real market conditions. We made a few important assumptions/tenets for this these auxiliary regressions. Namely, for ease of calculation, we decided the building would be four floors, the first three would have ten units each and the top would have four much larger premium units. Secondly, of the 44,000 SqFt. we would ascribe 4,000 to be common space (difference between real and usable square feet), recognizing that this is likely an underestimation of the actual common space required for a building this size.Our first regression represents the homogenous units of the first three floors. Each unit is assumed to have 3 bedrooms, 2 bathrooms, a deposit of $1621 (as calculated from the average of our data's deposit) unit confinement within one floor, unit security, unit bike storage, 1,100 square feet(as calculated from the average of 3 bedroom 2 bathroom units found in our data), a distance to campus of 1.7 miles and a distance to closest commercial grocery retailer of 1.5 miles. Our second regression represents the 4 premium units on the top floor. Each unit is assumed to have 4 bedrooms and 3 bathrooms, a deposit of $2263, confinement to one floor per unit, unit security, unit bike storage, 1,750 square feet, a distance to campus of 1.7 miles and a distance to closest commercial grocery retailer of 1.5 miles.

Introducing these numbers into our model yielded results of $1656.25 per month for the 3 bedroom rooms ($552.08 per person) and $2478.009 per month for the 4 bedroom premium units ($619.50 per person).

With our limited sample size we recognize that some of the variables we omitted from our original regression output might likely be significant given a larger data sample with greater variance. However, our results reinforced our original hypotheses. As we expected, rent per square foot in the Glenwood Riverfront area is considerably less than the average rent per square foot in the Eugene student housing complex. Rent per square foot in the Eugene market ranges between $2 and $3.5 per square foot. Using an average of the two different rental standards in our prospective Glenwood development, we calculate an average rent per square foot to be $1.46. As an estimate provided by our construction contact Anslow and DeGeneault, cost per square foot for the Glenwood area would be between $115 and $125 per square foot. From the Lane county Department of Assessment and Taxation, we were able to estimate and factor in monthly taxes for the Glenwood area, based upon the specification of our project construction costs. This turned out to be $5,002.50 per month. From local commercial real estate appraisers Duncan & Brown, we acquired an estimate of monthly operating expenses as a % of gross monthly revenue. This was quoted at between 28% and 30%. Using a $120 estimate as cost per square foot we can estimate a break-even point for the Glenwood development. Total construction costs are 5,280,000(120 x 44,000) and gross monthly revenue is 57,600 (1.46 x

[3] Appendix C

40,000). 57,600-21,687.62(monthly taxes + operating expenses) = 35,912.38 in net monthly revenue. 5,280,000/35,912.38 = 147.02→ 147 months. Given these estimates we can conclude that it would take a Glenwood riverfront complex 147 months or approximately 12.25 years rented at 100% capacity to break even in this model development.

APPLICATION OF THE MODEL

As mentioned above, in applying our hedonic price model for the University of Oregon student apartment industry to the Glenwood development, we can estimate the potential revenues a student housing complex could provide developers and the city planners of Springfield. We realize our estimate of 12.25 years for full repayment of costs fails to recognize other potential sources of income and costs such as omitted significant positive variables on rent or maintenance costs to the facility.

Additionally, we acknowledge that this model assumes that demand exists for such a property, which we could not properly determine given our resources and timeframe. Yet we believe flagship projects such as the downtown Capstone project, a proposal for a student complex that would house 1200+ students is a strong indication of the prolific demand in this market. We also recognize that changes in demand and supply can be very volatile in the short run, but hope that this model may still serve to capture the relevant ratios of rent to attributes, ratios that we believe won't significantly change with shifts in supply and demand for student apartment housing.

With that in mind, it is still difficult for us to make a firm recommendation for a student housing development in the Glenwood Development. At this point in time, it is nearly impossible to measure the full potential economic impact a student housing complex could have in the Glenwood district given that development plans are still in preliminary stages. However, to achieve the results of the Glenwood Development that the city of Springfield envisions, we do believe that a student housing complex is a reasonable option given the current budget restraints and goals for the city. For one, the costs of development for a student apartment complex is significantly cheaper than other alternative developments and may prove to be self-sufficient enough in the long term to begin attracting developers to the Glenwood region. In addition, if the city envisions a mixed-use development in the Glenwood region, then a student housing complex may serve as the perfect project to jumpstart potential future investment. By implementing a facility that could potentially bring in over 100 residents, the Glenwood region would immediately become more attractive to potential businesses and developers.

With more time and extensive analysis, a refined model could be used to compare the feasibility of a student apartment complex with other potential developments. Future hedonic rental models could be crucial components in cost benefit analysis for developers, investors, and local governments. Given the current circumstances of the Glenwood region, including the lack of developer and investor interest, our study leads us to believe that a relatively low cost student housing project that will target a specific demographic with its unique

set of attributes, could be an appropriate venture to jumpstart development in the Glenwood region.

FURTHER CONSIDERATIONS

Recognizing that 12.25 is probably too long a period to be advertising as a payback period for a development, it is up to the city of Springfield to make concessions in order to incentivize development. As an example, if Springfield fully abated the $60,030 in annual tax payments for the first seven years, it would reduce the payback time to ten years, after the seven years, the realized market value would increase over 1200%, or $4,884,000 which would more than fully pay back the tax abatements. This reduction in payback is not hugely significant considering the number of years the city would not be collecting tax revenues from this property. Unfortunately, the payback period for any type of rental development going into this area is going to be long because the premium on rent will be small. Due to the lack of external market value in the surrounding area, a new development here will not realize the mutualistic market value spillovers of a more attractive, less industrialized area. Additionally, the management company will be of great importance. According to Duncan & Brown local commercial real estate appraisals, small, independent management companies face large initial operating expenses, especially with respect to management, because on site management can cost up to 7% of gross monthly revenue. Thus a prospective development pitch may be better aimed at existing, larger property management companies that have reduced aggregate operating costs through economies of scale.

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ADDITIONAL RESOURCES

Courtside Apartment Complex information:http://livecourtside.com

Duck's Village Complex information: http://www.ducksvillage.com/

University of Oregon enrollment : http://registrar.uoregon.edu/statistics/facts_at_a_glance

Appendix A

Initial Regression Results with "RENTPERSQFT" dependent variable

Dependent Variable: RENTPERSQFT
Method: Least Squares
Date: 05/11/12 Time: 13:08
Sample: 1 145
Included observations: 95
White heteroskedasticity-consistent standard errors & covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	2.210686	0.372085	5.941340	0.0000
BEDROOMS	0.192112	0.053985	3.558649	0.0006
BATHROOMS	-0.206290	0.062928	-3.278207	0.0016
ADDITIONALUNITS	0.004729	0.003848	1.229010	0.2228
DISTANCETOCAMPUS	-0.102674	0.103380	-0.993164	0.3237
DISTANCETOEMXLINE	-0.066918	0.094584	-0.707498	0.4814
DISTANCETOGROCERYSTORE	-0.251378	0.104421	-2.407342	0.0185
FLOORS	-0.043512	0.029622	-1.468906	0.1459
RENOVATIONS	0.269316	0.086242	3.122799	0.0025
YEARSSINCEBUILT	0.002749	0.017615	0.156061	0.8764
DUM_BALCONY	0.001743	0.054736	0.031852	0.9747
DUM_BIKESTORAGE	-0.085097	0.060814	-1.399303	0.1657
DUM_COMPLEXSECURITY	0.086510	0.088452	0.978046	0.3311
DUM_DISHWASHER	-0.627793	0.276924	-2.267022	0.0262
DUM_EXERCISEROOM	-0.153008	0.309377	-0.494568	0.6223
DUM_SUSTAINABLEDES	-0.052943	0.091138	-0.580906	0.5630
DUM_UTILITIESNOTINRENT	0.173538	0.093302	1.859953	0.0667
DUM_WASHERDRYER	-0.026300	0.115541	-0.227623	0.8205

R-squared	0.518754	Mean dependent var	1.691391
Adjusted R-squared	0.412505	S.D. dependent var	0.292181
S.E. of regression	0.223952	Akaike info criterion	0.014103
Sum squared resid	3.861886	Schwarz criterion	0.497996
Log likelihood	17.33010	Hannan-Quinn criter.	0.209632
F-statistic	4.882440	Durbin-Watson stat	1.616259
Prob(F-statistic)	0.000001		

Appendix B

Final Regression Model – All included variables

$Rent_i = 251.95 + (83.81)bathrooms_i + (139.37)bedrooms_i + (0.59)deposit_i + (-277.08)distancetocampus_i + (-101.24)distancetogrocery_i + (82.06)DUM\_bikestorage_i + (-89.39)DUM\_dishwasher_i + (-338.85)\ DUM\_exercise_i + (733.86)DUM\_furnished_i + (237.31)DUM\_internet_i + (101.69)DUM\_security_i + (117.57)DUM\_utilities_i + (-45.80)floors_i + (83.19)renovations_i + (0.32)sqft_i + (-0.82)additionalunits_i + (1.92)distancetoEmX_i + (7.84)DUM\_balcony_i + (15.83)DUM\_sustainablecert_i + (39.70)DUM\_washerdryer_i + (-2.10)yrssincebuilt_i$

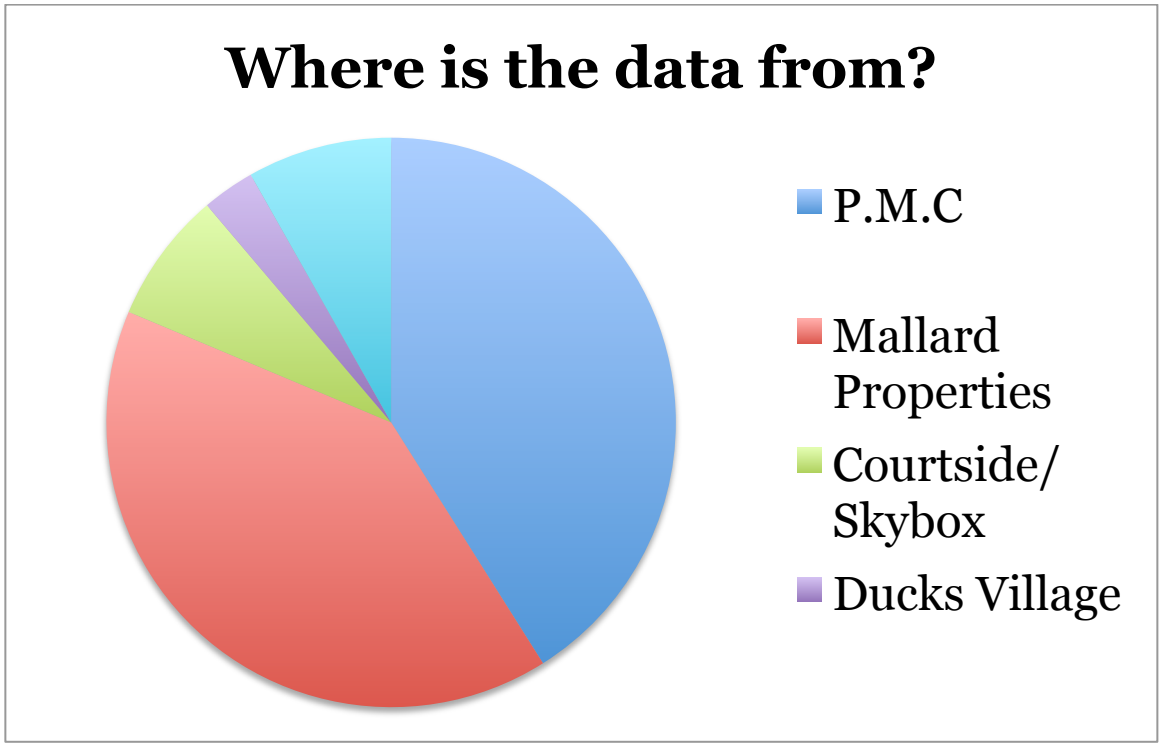
Appendix C

Final Regression Model – Application to Glenwood (3 Bedroom)

$Rent_i = 251.95 + (83.81)bathrooms_i + (139.37)bedrooms_i + (0.59)deposit_i + (277.08)distancetocampus_i + (-101.24)distancetogrocery_i + (82.06)DUM\_bikestorage_i + (101.69)DUM\_security_i + (-45.80)floors_i + (0.32)sqft_i$

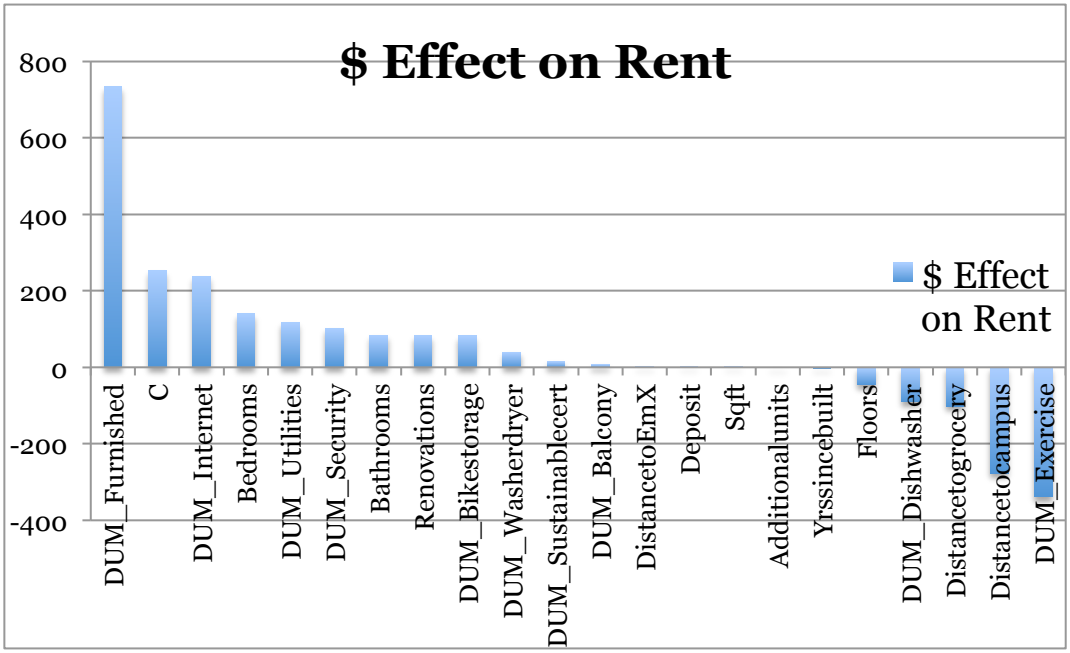
Appendix D

Data Collection Chart



Appendix E

Regression Results – Graphical Representation of Coefficients



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Prey Detection and Feeding Success of the Comb Jellyfish *Mnemiopsis leidyi* on Copepods in Still and Turbulent Waters

Clare Elizabeth Chisholm*, Environmental Science

ABSTRACT

The comb jelly or ctenophore, *Mnemiopsis leidyi,* is a voracious predator in both its native and non-native habitats. Though *M. leidyi* inhabits coastal waters that are frequently turbulent, previous feeding studies have been conducted in still water tanks. This study aimed to research feeding behaviors in turbulent waters, which is more representative of the natural environment. Interactions between the free-swimming ctenophores and copepod prey, such as *Acartia tonsa*, were observed and recorded in a laboratory turbulence tank (n = 73). Turbulence was created using submersible speakers, and the interactions were recorded using a video camera. Capture efficiency denoted interactions containing direct contact between copepods and *M. leidyi* that led to eventual capture, frequently after multiple contacts. Overall copepod capture efficiency was similar in still (48%) and turbulent (43%) water, as were the overall prey retention rates for each (still = 58%; turbulent = 57%). However, *M. leidyi* exhibited anticipatory responses, defined as altering the position of feeding structures, nearly twice as often in still (41%) waters than in turbulent (20%) waters. The hydromechanical "noise" produced by background turbulence may inhibit the capacity of the ctenophore to detect and respond to fluid motions produced by its prey.

1. INTRODUCTION

The lobate ctenophore *Mnemiopsis leidyi* is a planktonic predator native to the Atlantic coastal waters of North and South America, ranging from Buzzards Bay, USA (40°N) to Bianca Bay, Argentina (46°S) (Fig. 1; Colin et al., 2010; Mianzan et al., 2010; Costello et al., 2012). Ecologically important to its native range, *M. leidyi* has also become ecologically important in its invasive range, mainly due to its rapid population growth rates and high feeding rates on zooplankton and ichthyoplankton (Costello et al., 1999; Colin et al., 2010; Costello et al., 2012). In the last 30 years, *M. leidyi* has transitioned from its native waters to the Black Sea, Caspian

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Sea, Mediterranean Sea, North Sea, Baltic Sea, Sea of Azov, Sea of Marmara and the Adriatic Sea (Bright, 1999; Mutlu 1999; Finenko et al., 2006; Roohi et al., 2008; Colin et al., 2010; Costello et al., 2012). Introduced to these areas in the 1980s, it is likely that *M. leidyi* first invaded the Black Sea via ballast water and spread to the surrounding ecosystems (Mutlu 1999; Finenko et al., 2006; Roohi et al., 2008; Ghabooli et al., 2010, Costello et al., 2012). Due to the ctenophores self-compatible hermaphroditism, its tolerance to a range of temperatures, salinity and oxygen levels and its extensive dietary plasticity, *M. leidyi* has established itself as a prolific invader (Roohi et al., 2008; Ghabooli et al., 2010; Mianzan et al., 2010). Additionally, the invasion and explosion of *M. leidyi* in the European seas has been identified as a possible cause to of the collapse of fisheries in Eurasia, including that of economically important fish species, such as anchovies (Bilio and Niermann, 2004; Daskalov & Mamedov, 2007; Costello et al., 2012).

When observed feeding in still water environments, *M. leidyi* engages the ciliary lining in the auricles, creating a laminar feeding current (Fig. 2; Colin et al., 2010). This current causes large quantities of fluid to be swept between the oral lobes, allowing the ctenophore to entrain and retain prey very efficiently (Colin et al., 2010). This capacity to process large volumes of water has greatly contributed to the ecological success of the species, and is likely one of the primary influences on the devastation of planktonic communities (Mutlu, 1999; Finenko et al., 2006; Colin et al., 2010).

Information gathered in relation to the feeding habits of *M. leidyi* has been primarily conducted in still water settings; however, water movement frequently characterizes the natural ecological habitats of *M. leidyi*. Previous research has discovered that *M. leidyi* has a 74% success capture rate after contact occurs between predator and prey. However, capture success numbers fall substantially when initial contact between species occurs on the interior surface of the oral lobes (Costello et al., 1999). This is likely because physical contact with the oral lobe of the ctenophore elicits an escape response from the copepod. Considering the importance of fluid manipulation during feeding, background water motion is a likely influence on the predation behaviors of *M. leidyi*

Turbulence is defined as the time-varying movement of water, which can be produced by wind, waves, tides, coastal upwelling and the interaction with rough surface; then disperses heat, particles and organisms throughout the ocean (Robinson et al., 2007; Thorpe, 2007). Turbulence, being the natural state of the oceanic environment, often evokes variant responses in marine organisms such as copepods and ctenophores (Warnaars et al., 2006; Thorpe, 2007). Planktonic organisms have evolved in the presence of fluid motion and are able to detect and respond to turbulence and related fluid-mechanical cues (Warnaars et al., 2006; Thorpe, 2007). For the purpose of this research, turbulence was studied in relation to the interactions between *M. leidyi* and copepods. Copepods employ sensory hairs on their antennae called setae in order to detect changes in ambient turbulence (Kiorboe, 2008). Evidence exists that copepods are capable of distinguishing the differences between environmental fluid motion cues and the cues from other plankters; ambient turbulence does not necessarily elicit the bending of the setae of a copepod, which dictate whether an attack or escape response is appropriate (Kiorboe, 2008). In

contrast, the disturbance of water movement by predators, such as *M. leidyi*, may induce these responses from copepod individuals (Kiorboe, 2008).

The goal of this study was to compare the predator-prey encounters and feeding success rates of the adult *M. leidyi* on copepods in still and turbulent conditions. In both treatments, encounters between copepods and *M. leidyi* individuals were quantified to document the relationship between feeding success in turbulent vs. non-turbulent water. In particular, the following hypothesis was tested:

H_0: Increased turbulence has no effect on the success of the predator-prey interaction between *Mnemiopsis leidyi* and zooplankton species in terms of retention and capture efficiencies

H_1: An increase in turbulence causes an increase in the retention and capture efficiencies of *Mnemiopsis leidyi* when feeding on zooplankton species

It was expected that retention and capture efficiencies would increase with increased turbulence due to the amplified noise within ambient waters. Theoretically, this would allow for *M. leidyi* individuals to ambush prey more effectively, and retain prey more efficiently (Costello et al., 1999).

2. MATERIALS AND METHODS

2.1 COLLECTION

Specimens of the ctenophore *Mnemiopsis leidyi* and zooplankton prey were collected in August of 2011 at the Marine Biological Labs (MBL) in Woods Hole, Massachusetts. Ctenophore specimens between 2 and 4 cm were dipped from the surface water using beakers. Individuals were held in tanks of ambient seawater and observed within 24 hours of collection. Additionally, zooplankton were collected, primarily *Acartia tonsa*, using a 0.5 meter plankton net with 333 micrometer mesh.

2.2 TURBULENCE

Ctenophore-copepod interactions were observed at three flow levels: still water, intermediate turbulence (24 and 27 clicks) and high turbulence (30 clicks). Turbulence was generated following the methods of Warnaars et al (2006). A rectangular tank with a removable lid was designed out of Plexiglass (dimensions = 26 x 50 x 30 cm), with plastic mesh grids with 1-2 cm openings placed at opposite ends. Submersible speakers (Clark Synthesis AQ339) were connected to an amplifier and mounted behind the mesh grids at each end of the tank. Turbulence was produced using low frequency (30 Hz), out-of-phase (180°) sine waves that were generated using a computer program called “Test Tone Generator.” The alternation of the sine waves allowed the water to be pushed back and forth, which simulated energy dissipation levels in the natural environment.

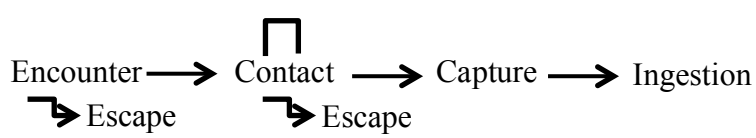
Each speaker was then turned to a specific volume, 0 clicks for still water, 24 and 27 clicks for intermediate turbulence, and 30 clicks for high turbulence. Clicks simply denoted the volume level of the speaker. The overall turbulence dissipation rate of the pooled data is as follows: mean ± SD = $3.75 \times 10^{-7} \pm 2.99 \times 10^{-7}$ m^2s^{-3}. This number can be compared to rates of turbulence dissipation measured at the ocean surface and in estuaries. Usually, the surface rates are less than 1×10^{-6} m^2s^{-3}, and estuaries can reach 1×10^{-3} m^2s^{-3}, though they rarely encounter these sorts of levels (Noh and Hyoung, 1999).

2.3 VIDEOGRAPHY

For each trial, 5-8 individual *M. leidyi* were introduced to the turbulence generator and allowed to acclimate for a minimum of 10 minutes. Interactions between *M. leidyi* and copepod prey were then filmed using a Sony HDR-HC9 handheld video camcorder, stabilized on a tripod. The tank was lit using LED lights, and the movement of individual specimens was tracked with the camera. Scale bars were included within the recording periodically, in order to provide spatial context for the interactions. The total film time was approximately 3 hours and 44 minutes.

2.4 VIDEO ANALYSIS

Video analysis was conducted using the film-editing software iMovie 2009 (Apple Inc., version 8.0.6). Videos were observed carefully to identify interactions between *M. leidyi* and copepod individuals. Video segments encompassing encounters between *M. leidyi* and copepods spanning five seconds or greater were selected for data collection. During the five-second clips, a minimum of 75% of the ctenophore body was required to be within the entire frame as well as the interacting copepod individual. Additionally, the segments could not have more than one *M. leidyi* specimen within the frame. Video clips involving an interaction were subsequently analyzed and components of the predation process were coded following the methods of previous studies regarding *M. leidyi* predation behaviors (Costello et al., 1999); encounters were analyzed based on the following predation sequence:



Each component is described in Table 1. Similar to research conducted by Costello et al. (1999), the two variables evaluated were retention and capture efficiency, which were defined in as the following:

$$\text{Retention Efficiency} \quad \frac{\text{no. of}}{\text{no. of}} \quad \text{x10}$$

$$\text{Capture Efficiency} \quad \frac{\text{no. of}}{\text{no. of}} \quad \text{x10}$$

The two efficiencies quantify two key elements of the encounters. Retention efficiency evaluates the ability of the ctenophore to retain prey post-contact. Comparatively, capture efficiency quantifies the final post-encounter outcome of *M. leidyi* and zooplankton individuals, disregarding intermediate interactions between the two species. Retention and capture efficiencies were calculated using the aforementioned equations and then statistically analyzed for significance using a chi-square test (Microsoft Excel for Mac 2011, Version 14.3.2).

3. RESULTS

3.1 RETENTION AND CAPTURE EFFICIENCY

A total of 73 encounters were observed between *Mnemiopsis leidyi* and copepods during the study. Of these encounters 29 occurred in still water and 44 occurred in turbulent water. Retention efficiency for still and turbulent waters was similar (Fig. 3). In still water, the retention rate was 58.3%, and turbulent water interactions exhibited a retention rate of 57.6%.

Capture efficiencies between treatments varied more than retention efficiencies, though there was no significant difference. Interactions occurring in still water had a capture rate of 48.3%, while turbulent treatments resulted in a capture rate of 43.2% ($X^2 = 0.124$, df = 1, p = 0.724).

3.2 VARIATIONS IN ENCOUNTER ORIGINS

In both treatments, encounters originated through two processes: laminar flow generated by *M. leidyi* (n = 53) and movement of copepod individuals towards *M. leidyi* prior to interspecies contact (n = 20; Fig. 4). The majority of encounters in this study originated through laminar flow created by *M. leidyi* individuals, with little variation between still and turbulent treatments (still = 69.0%; turbulent = 70.5%). Less than half of the encounters began with pre-contact motion by the copepod prey, again with little difference between the two treatments (still = 31.0%; turbulent = 29.6%). No significant difference existed between still and turbulent encounter origins ($X^2 = 0.052$, df = 1, p = 0.820).

3.3 ENCOUNTERS AND CONTACT RELATIONSHIP

The majority of interactions between the ctenophore *M. leidyi* and copepods involved multiple contacts. Overall, encounters with multiple contacts (n = 45) occurred more than twice as often as interactions containing single contacts (n = 23; Fig. 5). Additionally, interactions in turbulent waters containing multiple contacts (42.6%) occurred nearly twice as often as encounters with multiple contacts in still waters (23.5%). Despite these differences in frequency, there was no significant difference in contact frequency between still and turbulent treatments ($X^2 = 0.124$, df = 1, p = 0.724).

Encounters with and without anticipation were evaluated based on the number of contacts within each interaction. When anticipation was not present (Fig. 6), encounters in turbulent

waters occurred more often, both with single (28.6%) and multiple contacts (33.3%). The proportion of encounters with single contacts in still water was 11.9%, less than half that of turbulent encounters. Additionally, in still water encounters without anticipation, multiple contacts (26.2%) occurred more than twice as frequently as single contacts. However, when the treatments were compared, no significant difference between proportion of encounters and contact number was seen in still vs. turbulent waters ($X^2 = 2.249$, df = 1, p = 0.134).

In contrast, anticipation occurred more often in still waters, including encounters containing single (26.7%) and multiple (33.3%) contacts (Fig. 7). While an increase from single contact to multiple contacts with anticipatory behaviors was seen, no significant difference was exhibited ($X^2 = 1.238$, df = 1, p = 0.266). In addition, interactions with anticipatory movement and multiple contacts (26.8%) occurred more often than single contacts (13.3%) in turbulent waters.

3.4 PREY DETECTION AND PREDATION SUCCESS

The ctenophore *M. leidyi* frequently employs anticipatory behaviors upon the detection of nearby prey. In still waters, anticipatory movements were displayed by the ctenophore 41.4% of the time (Fig. 8). In contrast, in turbulent waters anticipatory behaviors were exhibited in only 20.5% of the interspecies encounters. However, when no anticipatory movement was present the proportion of encounters between *M. leidyi* and copepods displayed a large increase (79.6%). A higher proportion of encounters occurred in still water without anticipatory movement (58.6%) than with anticipatory movement. There was a significant difference between interactions with anticipatory behavior and those without anticipatory behavior in still and turbulent water ($X^2 = 10.256$, df = 1, p = 0.001).

The capture efficiency of encounters with and without anticipatory movements in still and turbulent waters displayed opposing trends (Fig. 9). For still water interactions the capture efficiency of *M. leidyi* was higher when an anticipatory motion was present (27.6%), and lower without anticipatory behavior (20.7%). In contrast, *M. leidyi* experienced greater capture efficiency success when no anticipatory behavior was present in turbulent waters (31.8%), and a much lower rate of capture efficiency when anticipatory behaviors were present (11.4%). Additionally, when capture efficiency and presence of anticipatory behavior was compared between still and turbulent treatments a significant difference was observed ($X^2 = 9.342$, df = 1, p = 0.002).

4. DISCUSSION

4.1 RETENTION AND CAPTURE EFFICIENCY

As previously discussed, encounters between *Mnemiopsis leidyi* and copepods were analyzed in both turbulent and still water. It was expected that retention and capture efficiencies would be lower in still waters than in turbulent waters. However, similarities in retention and capture efficiencies between treatments were observed, suggesting that *M. leidyi* appears to be an equally effective predator on copepods in both still and turbulent waters.

While this relationship was unexpected, it led to additional questions and observations regarding ctenophore feeding behaviors. It is possible that *M. leidyi* employed different predatory tactics within the two treatments, allowing individuals to detect and consume prey efficiently in both still and turbulent environments. These varying behaviors could include anticipatory movements, altered body positioning and selective feeding based on copepod life stage (Costello et al., 1999; Waggett and Costello, 1999). Previous studies have indicated that *M. leidyi* preferentially select late-stage and larger copepods over early-stage and smaller copepods when employing anticipatory behaviors (Costello et al., 1999; Waggett and Costello, 1999).

4.2 ENCOUNTER ORIGINS AND FREQUENCY OF *M. LEIDYI* ANTICIPATION

The origin of encounters between *M. leidyi* and copepods varied little between still water and turbulent water treatments. In both treatments, laminar flow was most often employed by the ctenophore, in order to entrain copepods. In contrast, prey motion much less frequently served as the point of origin for ctenophore-copepod interactions. These results did not correlate with previous research, as earlier studies displayed that the majority of encounters began with prey motion (Costello et al., 1999). However, these studies observed interactions between the adult-stage copepod *Acartia tonsa* and late-stage *M. leidyi* individuals (Costello et al., 1999; Waggett and Costello, 1999). The study performed by Costello et al. (1999) found that more frequently swimming by adult *A. tonsa* led to the interspecies encounters, but interactions between the smaller copepods *Oithona colcarva* were usually initiated by the laminar flow produced by *M. leidyi*

It is possible that the variation between results of this study and the results of the previous studies is due to the disparity in copepod life-history stage and species. While the majority of copepods in this study were identified as *A. tonsa* it is likely that several of these were *A. tonsa* nauplii individuals, which are substantially smaller than their adult counterparts. Additionally, it has been observed that *A. tonsa* nauplii cause a reduced disturbance in surrounding fluid when compared to adult-stage *A. tonsa*, causing the ctenophore to employ entrainment through flow when feeding on smaller individuals (Costello et al. 1999; Waggett and Costello, 1999). These factors led to the conclusion that the high frequency of encounters observed in this study originating with laminar flow are likely due to the increased presence of the smaller *A. tonsa* nauplii.

In addition to employing laminar flow more frequently, *M. leidyi* individuals in this study also seldom exhibited anticipatory movements in either still or turbulent treatments. Again, these data contradict the findings of previous studies, which found that anticipatory behavior was often exhibited in still waters (Costello et al., 1999). Similarly, these differing results regarding anticipatory behavior may be linked to the size of the copepods present (Costello et al., 1999; Waggett and Costello, 1999). In their study, Costello et al., (1999) observed that *A. tonsa* nauplii rarely elicited an anticipatory response from *M. leidyi*, likely due to their decreased disturbance to the background water motion. These slow-moving, small prey are far more likely to be entrained by the laminar flow generated by *M. leidyi* (Waggett and Costello, 1999).

4.3 INTERSPECIES CONTACT AND ANTICIPATION

The majority of encounters in this study involved multiple contacts between species, regardless of still or turbulent treatments. However, a larger proportion of encounters in turbulent water demonstrated multiple contacts when compared to still treatments. Additionally, encounters containing multiple contacts in turbulent waters also occurred more frequently than encounters exhibiting single contacts in turbulent waters. This is possibly due to a lack of prey detection in turbulent waters, and the multiple contacts followed before *M. leidyi* could effectively capture the prey. Additionally, similar to the results of Costello et al. (1999) the bulk of escapes by copepods in this study occurred when a single contact was present, regardless of still or turbulent conditions.

In addition to the proportion of encounters with single and multiple contacts, the relationship between contact number and presence of anticipatory behaviors was analyzed. Similar to previous studies, an increase in encounters with multiple contacts and anticipation were observed in both still and turbulent waters (Costello et al., 1999). However, contradicting trends were seen in encounters exhibiting no anticipation. Earlier research found that interactions without anticipation exhibited a single contact the majority of the time, and infrequently had multiple contacts (Costello et al., 1999). While encounters in turbulent waters may display these opposing results due to the difference in background water motion, it is likely that encounters in still water differ based on prey species and size once again (Costello et al., 1999; Waggett and Costello, 1999).

As *M. leidyi* continues to expand its native and non-native range, knowledge surrounding its feeding behaviors is increasingly important. This research provides further information regarding the predation tactics and interactions of *M. leidyi* with copepods, such as *A. tonsa*, in a system replicate of its natural environment. It is possible that *M. leidyi* has shown itself to be such an effective invasive species because it successfully feeds on small prey, though it selectively anticipates larger prey (Costello et al., 1999; Waggett and Costello, 1999).

Continued examination of the feeding behaviors of *M. leidyi* in relation to varying environmental factors, such as salinity, temperature and life stage of prey and predator, would be beneficial in the understanding of the species' invasive tendencies. Additionally, research on other lobate ctenophore species may also provide insight into their influence on zooplankton communities. It remains clear that ctenophores, and *M. leidyi* specifically, play an important ecological role in the global food webs. Their consumption of species existing on some of the lowest trophic levels allows *M. leidyi* to substantially impact both native and non-native ecosystems.

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TABLES AND FIGURES

Variable	Description
Encounter	Interaction between ctenophore and copepod within the encounter zone, initiated either by direct contact between ctenophore and copepod or by an anticipatory response (e.g. oral lobe folding) by ctenophore prior to contact with copepod. The encounter zone was defined as the area bounded on the sides by the interior lobes of the ctenophore and extending anterior to the lobes for 3 mm (approximately 2 *Acartia tonsa* body lengths). Encounters terminated in either an escape from the encounter region or capture of the copepod by the ctenophore
Encounter origin	Means of encounter initiation; either flow entrainment or self-propelled swimming by the copepod. Copepod motion relative to surrounding flow was readily confirmed by visually comparing copepod velocities with those of surrounding particles entrained within flow field
Contact	Physical collision of predator and prey bodies. An encounter could entail multiple contacts if the copepod was not retained and collided with another portion of the ctenophore's capture surfaces. Contacts with exterior portions of the ctenophore's body (e.g. lobe exterior) were not recorded as contacts because these could not result in capture and were outside the encounter zone
Escape	Evasion of capture by a copepod after encounter with a ctenophore; the copepod must have left the encounter zone. Contact was not required
Capture	Copepod subdued and consumed by ctenophore
Anticipatory response	Lobe or auricle motion of ctenophore in response to copepod prior to actual contact
Prey motion	Motion of copepod prey in the vicinity of the ctenophore prior to contact
Number of contacts	Number of contacts between the ctenophore and copepod during an encounter
Encounter outcome	Capture or escape of a copepod as a result of an encounter

Table 1 Patterns of copepod-ctenophore encounters (Costello et al., 1999).

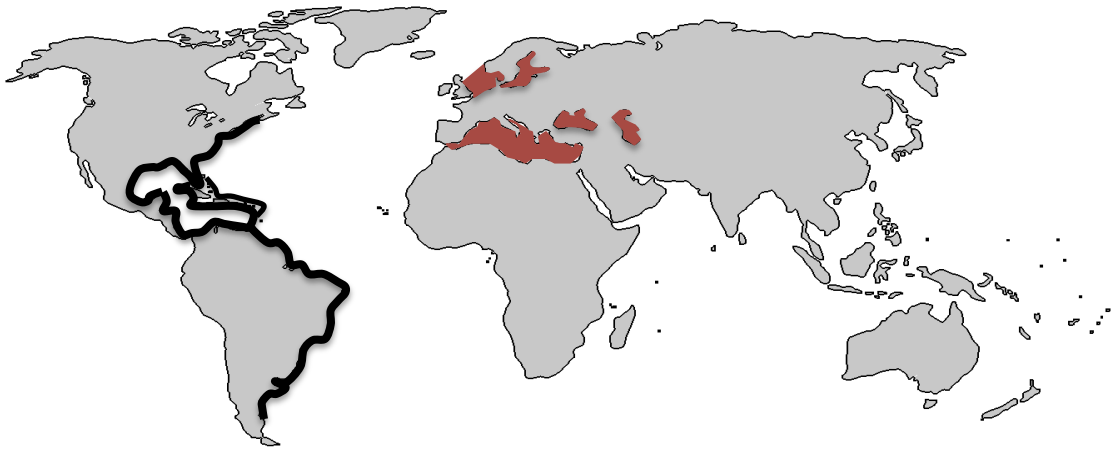

Figure 1 Map of the native and invasive ranges of *Mnemiopsis leidyi*. The *black line* represents the native range of the species and the red represents the invasive territory.

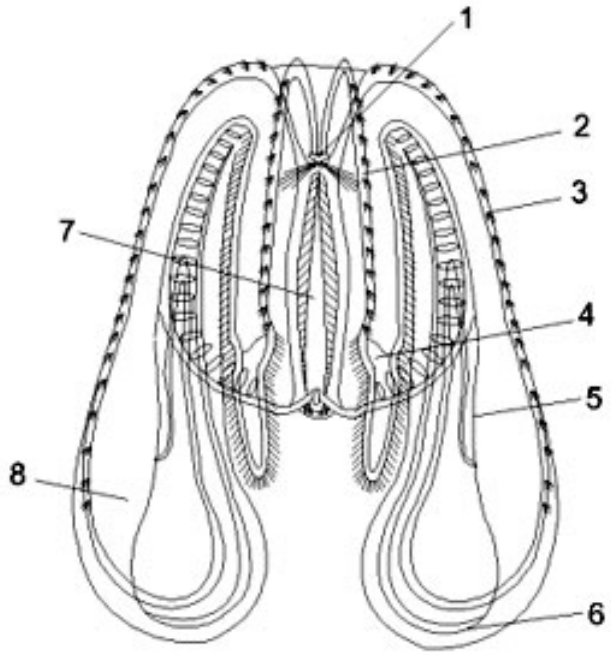

Figure 2 *Mnemiopsis leidyi*. (1) aboral organ, (2) subtentacular row of comb flappers, (3) subsagital row of comb flappers, (4) auriculus, (5) subsagital tube, (6) translobal tube, (7) tentacular tube, (8) lobe (Shiganova, 2000).As compared to 2011, the 2012 sediment size distribution in Middle McKenzie side channel 4 shifted toward a smaller median pebble size with an increase in D_{84} in count 1, while median pebble size increased with no detectable change in D_{84} values for count 2 (Figure 2). For count 1, the D_{50} size class decreased from 45-64 mm to a size class of 32-45 mm and the D_{84} size class increased from 91-128 mm to 128-181 mm. For count 2, the D_{50} size class increased from 32-45 mm to 45-64 mm and the D_{84} size class was recorded at 91-128 mm both years.

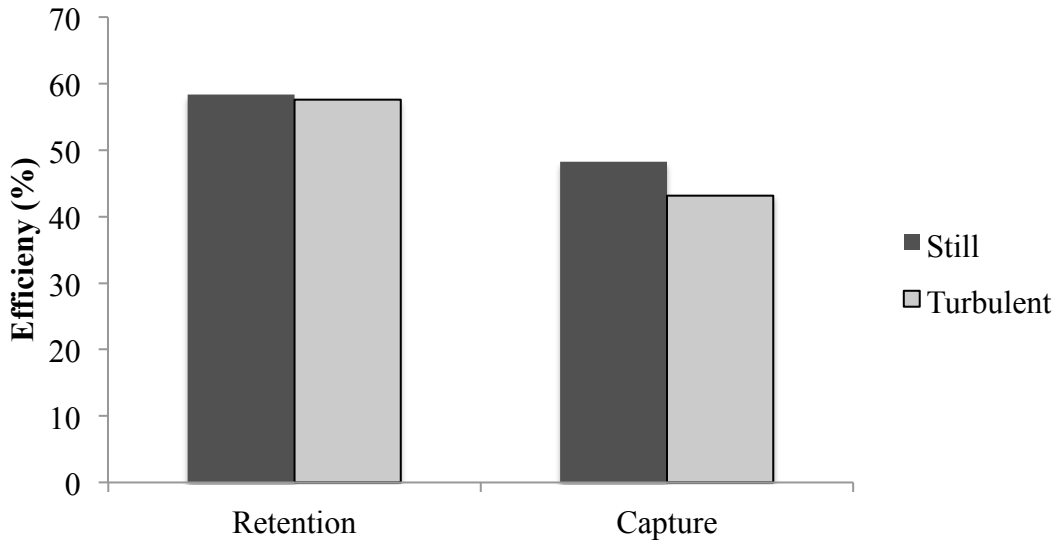

Figure 3 Retention and capture efficiencies of encounters between *Mnemiopsis leidyi* and copepods that occurred in still (n = 29) and turbulent (n = 44) waters.

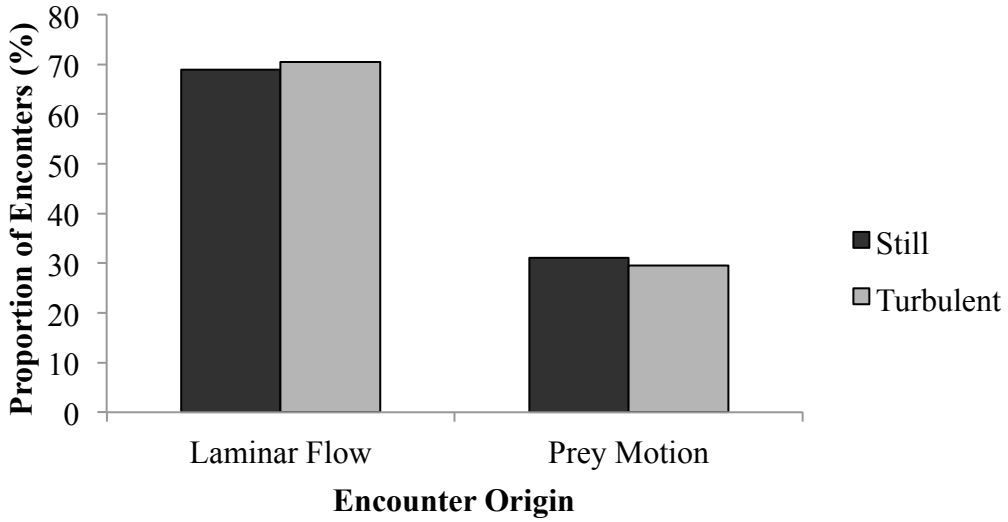

Figure 4 Origin of encounters between *Mnemiopsis leidyi* and copepods in still and turbulent water treatments. Encounters began with either entrainment by *M. leidyi* (laminar flow) or independent movement by copepods (prey motion).

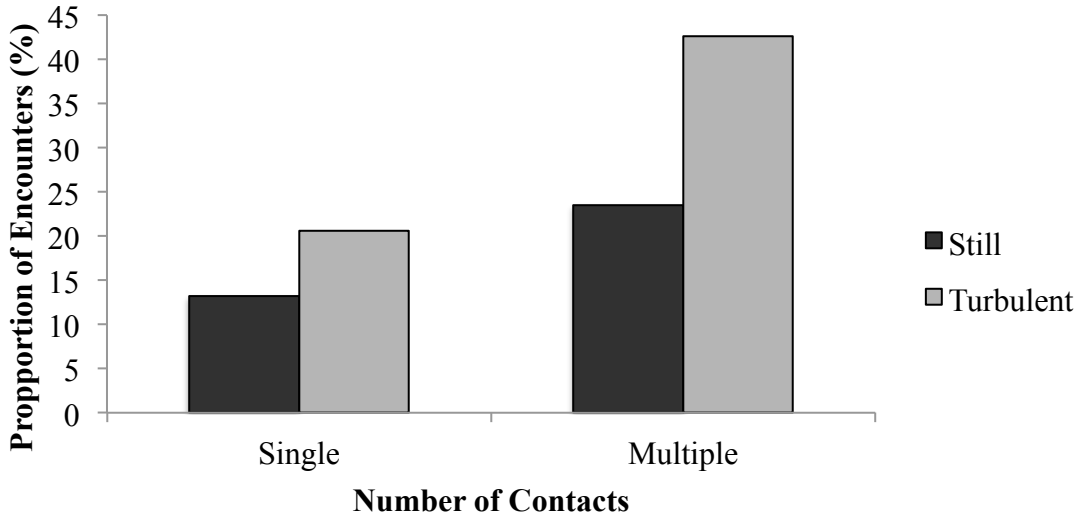

Figure 5 Frequency of encounters containing single and multiple contacts between *Mnemiopsis leidyi* and copepods in still (n = 25) and turbulent (n = 43) waters.

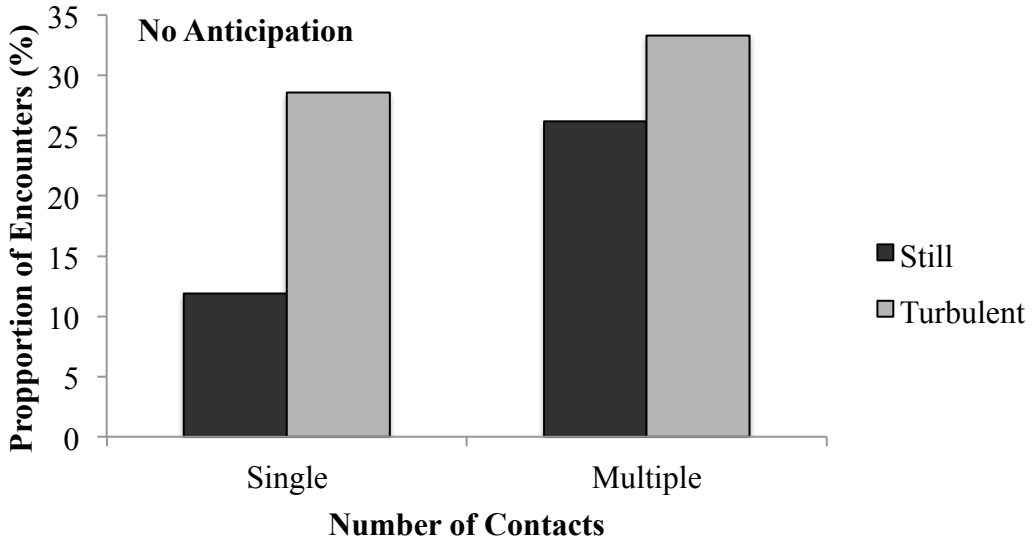

Figure 6 Encounters between copepods and *Mnemiopsis leidyi* individuals exhibiting no anticipatory behaviors with single or multiple contacts. Still (n = 16) and turbulent (n = 26) treatments were compared.

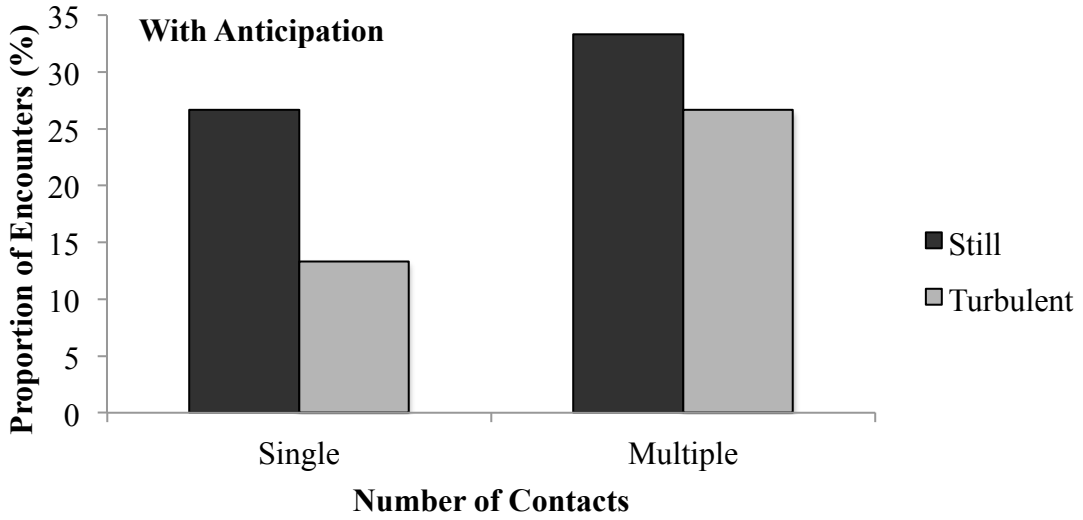

Fig. 7 Encounters between copepods and *Mnemiopsis leidyi* individuals exhibiting anticipatory behaviors with single or multiple contacts. Still (n = 9) and turbulent (n = 6) treatments were compared.

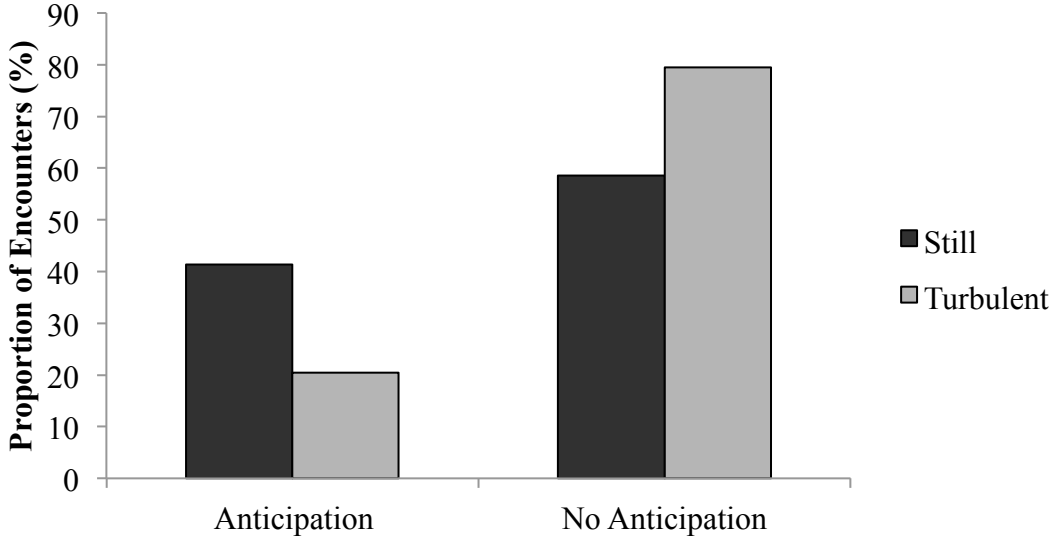

Fig. 8 Proportion of encounters between *Mnemiopsis leidyi* and copepods containing anticipatory behaviors in still (n = 29) and turbulent waters (n = 44).

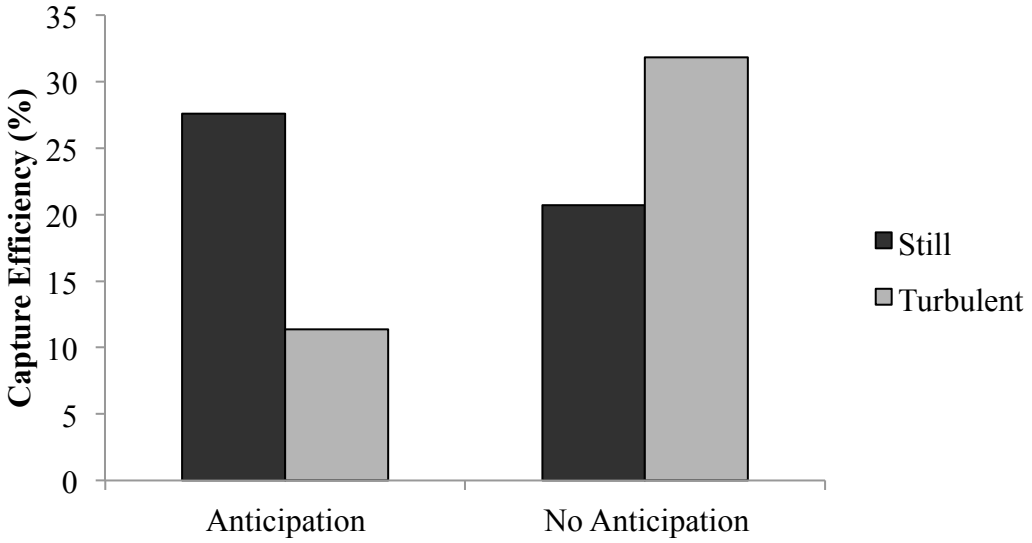

Fig. 9 Capture efficiency of the ctenophore *Mnemiopsis leidyi* when feeding on copepods in encounters containing anticipatory behaviors in still (n = 29) and turbulent waters (n = 44).

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The Virgin Knight: Spenser's Embodiment of Duality in Elizabethan England

Chelsea Arsenault, English

ABSTRACT

Edmund Spenser's poetry notoriously battles itself, contorting the surface of his poetical works into an ambiguous representation of how he perceived Elizabethan England in terms of theology, sexuality, nobility, and ideology. Written as what he termed "an historicall fiction[sic]," Spenser allowed his imagination to capture and epitomize the perspectives of Elizabethan society, but in a twisted fashion. The primary focus of appearance versus reality consumed him and became an encompassing factor of his work. In fact, he allowed one of his protagonists to become the embodiment of this struggle: Britomart, the virgin knight, who assumes a life of chastity and tribadism; ferocity and delicacy; the penetrator and the penetrated. Her conflicting roles as a chaste woman who exceeds the boundaries of expectation for her gender, encompasses her identity as an androgynous persona who refuses to abide by her expected gender performativity. When she confronts Malecasta at the House of Ioue, she becomes exposed to her conflicting, tense nature that fuels her essence as a penetrating virgin, allowing Spenser to indirectly expose Elizabethan England to restrictions on gender roles and sexuality due to his wordplays with language, means of representation, and repeated notions of dualism. Britomart, the virgin knight, embraces her character while serving as a canvas for Spenser to echo or defy common ideologies in Elizabethan England in terms of sexuality, chivalry, and identity.

The poetry of Edmund Spenser emerged in Elizabethan England from the struggle between two opposing elements of his nature: his drive for material ambition—dreams of wealth, importance, titles—which collided with his curiosity involving mystical idealism. These conflicting elements constantly surface in his poetical works, appearing in the form of a tense duality that is weaved with an opposition, taking the form of light versus dark, mysticism versus temporality, or appearance versus reality. In his work *The Faerie Queene,* he exaggerated this notion with metaphorical language to exemplify the tense duality. One character in particular however, who is introduced in Book III, becomes an encompassing image of conflicting attributes. Britomart, the female knight and protagonist, represents the inconsistency of appearance by remaining antithetical to her own reality. She pursues a man with vigor, but remains chaste; she disguises her femininity with armor, but is physically beautiful; and she

identifies as both an aggressive knight, but nonetheless remains a delicate virgin. The tension revolving around Britomart's character summarizes the prime concept of *The Faerie Queene,* because the poem's duality becomes embedded within a persona. The virgin knight's duality becomes exposed during her stay at the Castle of Ioue, revealing the conflicting elements regarding her androgynous identity— her sexuality and gender—while serving as a direct, yet dualistic, challenge to Elizabethan England.

The English Renaissance hosted a plethora of new ideas and ideologies, revolving around literature, medicine, theology, law, astrology, and many other emerging factors that influenced society and its quotidian. Along with these new perspectives, the notion of the "hermaphrodite" surfaced in the face of literary and scientific works. However, this anatomical term correlated with sexual pursuits, becoming perceived as a "type of monster... correlative to same sex lovers, for it afforded the prospect of interchanging conventional gender roles in sex, and thus appeared to confound masculine and feminine functions, upset assumptions of clear gender distinction, and challenge restriction of coitus to encounters of opposite sexes" (Borris 228). The perception that commonly circulated during the English Renaissance, pertaining to the concept of performing outside of acceptable gender roles, became denoted as "monster-like," discouraging rebellion while emphasizing standard heteronormativity. In terms of Britomart's sexuality, she becomes perceived as a conundrum because she denies the sexual pursuit of another woman for the sake of preserving her womanhood as a chaste virgin, yet seizes the opportunity to express her sexuality in an aggressive, "masculine-associated" fashion that corresponds with her knighthood. Britomart's heroic womanhood reappears throughout the text, emphasizing her masculine traits while complimenting her feminine qualities.

When Britomart wakes to find Malecasta, her hostess for the night while resting at the Castle of Ioue, lying next to her in bed, her sexuality becomes compromised because she is presented with the temptation that could compromise her virtuous ways for a same-sex, erotic encounter. However, because she possesses masculine traits in a female body, her sexual encounter allows her to mimic a tribadic response—when a woman dominates and penetrates another woman—which allows her to remain a woman while continuing to assert her male dominance in bed. In DiGangi's text "Fulfilling Venus," he notes that "what is at issue in condemnations of the tribas… is not homoerotic desire but gender transgression: the tribas was a 'masculinized, phallic woman' (Halperin) or a 'butch' (Pellegrini) who violated the cultural norms of female passivity" (DiGangi 65). By defining a tribade as a woman who defies patriarchal norms with aggressive sexual acts, DiGangi proposes that a woman becomes a threat due to the fact that she refuses to be passive, and instead assumes a more penetrating (and dominating) role that is often reserved for a male in a patriarchal society. Therefore, to be a tribade, a woman must defy this traditional gender role in terms of sexual, penetrative acts and verbal or mental aggression, most often occurring in a female-female bond. Britomart encompasses these traits, and when she awakens to see Malecasta lying in bed next to her, she refuses to compromise her own virginity and reacts when she "lightly lept out of her filed bed,/ And to her weapon ran, in minde to gride/ The loathed leachour" (FQ III.i.63). Her immediate intuition involving the pursuit of a weapon instead of sexual action represents her intense aversion towards losing her virginity while "in

minde to gride" Malecasta. The use of the word "gride," implying the desire to pierce and inflict pain, reflects how her sexual energy influences her immediate response to violently attack the "leachour" who has the intention of destroying her vow to chastity (OED Online). It also symbolically implies a tribadic response to the situation, allowing her to be the penetrator and not the penetrated. This aggressive stance adumbrates that she preserves her virginity and encourages her masculine side to overwhelm the sexual encounter, enforcing her desire to retain that dominating male perspective that she carries. Britomart's immediate response to Malecasta's pursuit insinuates that she guards her virginity when it is openly threatened, but she uses extreme and aggressive measures that parallel tribadism.

The notion of chivalry, which Britomart identifies due to her male exterior and battle-ready mentality, was perceived as a warrior code reserved for males since its emergence in the Middle Ages. Stemming from the French word "chevalrie," it literally meant "skill on horseback," but later evolved into a warrior code that stressed strength, conquest, and renown (McCoy 16). It becomes important to note that in the Elizabethan era, chivalry was "bound by social circumstances because they were composed for courtly performance" and were "devised to mediate conflicting interests within the ruling class" (McCoy 4). Spenser's consistent allusion to the conflict between appearance and reality becomes embedded in a figure of chivalry, but further perpetuates this notion by allowing a traditionally male-reserved space to be occupied by a female. Also, by personifying Britomart as a woman who exceeds the expectations in a role reserved for men to woo and revere women, he provokes the compromise of her sexuality. His detached perspective on the chivalric code is clearest when he twists it to exaggerate how all the traits that were solely correlated for a male become Britomart's strengths, as she respects and illuminates these virtues throughout her quest in *The Faerie Queene*. This notion allows her to be perceived as an invader to this male-reserved code while threatening the code of patriarchy.

Although Britomart conscientiously abjures and conceals the physicality of her female gender, traversing the boundaries of a feminine role, she does not assume the identity of a hermaphrodite or transgendered individual. She becomes physically perceived as a male, a knight who relies on her armor to signify her desired gender and the power that it conveys. At the Castle of Ioue, where she encounters the lustful Malecaste, Britomart refuses to disarm her armor contrary to the wishes of the Lady, "(For she her sexe vnder that straunge purport/ Did vse to hide, and plaine apparaunce shone:)" (FQ III.i.52). Britomart consciously continues to perpetuate the notion that she is a male knight by retaining her physical male disguise. Fisher notes that "'a man's identity' had, prior to the Renaissance, been 'defined on the basis of patrilineal inheritance' and linked this ability to reproduce himself, but over time, an 'emergent culture' of 'performative masculinity' developed in which masculine identity was secured through the sexual 'conquest' of women" which was visibly broadcasted by armor—most notably the codpiece (69). The importance of the male façade, exaggerated by armor, exposes the power and prey distinction between the sexes. In terms of Britomart's identity as a male in the House of Ioue, she has the desire to propagate herself as a male through her armored exterior, which controls Malecasta's explicit sexual emotions that develop due to Britomart's assumed male physique and, therefore, role. Because Malecasta lustfully "told her briefe,/ That but if she did

lend her short reliefe,/ And do her comfort, she mote algates dye," Britomart holds a sense of control over Malecasta due to the love she feels for Britomart, the knight (FQ III.i.530). The power Britomart gains from playing her male role acts as a means of dominance over the woman due to her knightly stature and Malecasta's irrefutable attachment to the knight. Ironically, the attention she attracts from Malecasta develops into a proposed sexual encounter that equalizes the power role, but while Britomart's exterior remains male, she retains the same power as a male. Her physical exterior conflicts with her inner virgin femininity, allowing the tension to build as Malecasta forcefully treats her in accordance with her male façade.

Since Britomart is frequently misinterpreted as a male, she is forced to confront the issues that occur with her anomalous identity that counteract her feminine virtues. For example, the misconception attracts problematic sexual encounters despite her chastity and consequently requires her to fight the alluring situations. When Malecasta pursues her, she wholeheartedly believes she's seducing a male knight since Britomart refuses to remove her armor and expose her female gender. As a result, Malecasta lies in bed with the intention of sleeping with the male knight Britomart, only to discover that she is "the warlike Mayd/ All in her snow-white smocke, with locks vnbownd,/ Threatning the point of her auenging blade" (FQ III.i.63). Britomart's character as "the warlike mayd" resonates as a female with the title as a "mayd," but one who antithetically possesses male tributes, since she is also perceived as "warlike." She perpetuates this male image with her swift and warrior-like actions, "threatning the point of her auenging blade," but the comedic perception of a pure and chaste woman in her "snow-white smocke" (which symbolizes her chaste position) exaggerates the amalgamate of her gender roles. The pure, physical beauty of a woman linked with the aggressive tension of a man encompasses Britomart's dual persona to embody her male and female attributes.

Britomart's identity in Spenser's work is not tethered to the challenge of representing a direct confrontation to the philosophies of patriarchy, however. She is also chosen as the exemplar of chastity to exemplify common standards during the Elizabethan era. In the Renaissance, women have been perceived as a complex gender that either paralleled the virtuousness of the Virgin Mary or represented the devil's gateway as an unchaste sexual predator. The feminine stereotype circulating throughout the years of the Renaissance perpetuated the ideology that a woman was valued for her beauty, denoting her physical attractiveness as her worth and putting her sexuality on a pedestal while emphasizing her frailty and value stemming from domesticity (Brown, MacBride). Therefore, chastity became one of the main attractive qualities that a woman could offer a man, and along with this virtue, the image of weakness. Spenser introduces Book Three of *The Faerie Queene* with an illustration of Chastity, enunciating its importance as "That fairest virtue, far above the rest" (FQ III.ii). Throughout the poetical work, Britomart's persona reflects a representation of Chastity, allowing her two main identities (penetrator and penetrated) to coalesce as one representative entity that fuels her sexuality.

Britomart's conflicting image sparks intensive debate pertaining to whether or not she is a delicate virgin, passively defending herself against penetration, or whether she is an aggressive knight who will pierce before she becomes pierced. Britomart's image as an assertive knight

contrasts heavily with her persona as a virgin, exaggerating the binary between her gentle and her violent characteristics. As a virgin, she stereotypically fosters a tender and innocent image capable of trusting easily. She is preyed upon by Malecasta as "the bird, that knowes not the false fowlers call,/ Into his hidden net full easily doth fall" (FQ III.i.54). The simile denoting her character to a gentle bird, which commonly evokes the image of a beautiful and innocent creature, depicts Britomart as a weak virgin woman easily preyed upon by the malintent of Malecasta. Her threatened virginity in this instance becomes her identity, exaggerating her position as a delicate and chaste woman who is susceptible to succumbing to a dominating power's will. The propagation of this stereotype encompasses Britomart because she is unknowingly preyed upon by Malecasta. However, this weak version of Britomart, the version where she becomes the prey as opposed to the predator, contrasts heavily with her aggressive and unforgiving warrior image.

Spenser's devotion to Chastity also becomes a devotion to Britomart, and he represents her by saying that she serves as a mirror of this perfection. According to him, if an artist had to replicate her chastity, "his daedale hand would faile, and greatly faynt/ … In picturing the parts of beauty daynt,/ so hard a workemanship adventure darre,/ For fear through want of words her excellence to marre." (FQ III.ii). He applauds her beauty and chastity to the extent that it becomes an accolade, but Spenser twists his language to introduce the tension that exists between her chastity and warrior-like presence. The resulting effects on the artist trying to replicate her beauty are not positive, and in fact appear to be violent and destructive. The artist faints and loses his notorious ability to craft anything from "his daedale hand," pronouncing the artist's prior infallibility concerning his skill, and her presence strikes fear into the illustrator to the extent that he shouldn't dare to try his hand at his "workemanship," because he would inevitably "marre" his work. However, the endorsed image of Chastity and its correlation with Britomart's embodiment allow her to be perceived as a beautiful and desirable woman. The fact that the language alludes to her warrior-like image as well however, instigates the tension in her character.

The divide between Spenser's praise to Chastity and his references to an image of aggression epitomizes Britomart's dual personality, which he enunciates through his language and use of wordplay. Anderson notes that "Spenserian wordplay" occurs often, and enunciates how "Spenserian etymology, at its most characteristic, does not look simply through the word to the thing but via the word to another story" (126). She describes how there is a sense in which it becomes necessary to look through the word, or dissect it for an alternative meaning to reveal Spenser's hidden message. His use of language allows it to resonate with a dualistic meaning, which he embeds in Britomart's existence when he describes her and her conflicting essence. For example, in the same introduction to Book III, Spenser advises virtuous women to regard their chastity in the same way that one would admire a portrait—but this is merely the surface interpretation. He says "to all ladies Which have it profest,/ Neede but behold the pourtraict of her hart" (FQ III.ii). He recommends that Britomart follows her chaste virtues by regarding her heart and admiring its attractiveness, which was a typical warning for a woman of the

Renaissance; however, the spelling of the word "hart" in this quote indulges in an alternative meaning that results in an ambiguous perception of Britomart's identity.

Britomart's notorious conquering of males throughout *The Faerie Queene* allows this portrait of the "heart" to contort into a symbol of her success as a knight who dominates other males. The spelling of the word "hart" surfaces throughout the poem, but most dramatically affects Britomart's character when Spenser uses a particular spelling to contort her identity when referring to Malecasta's pursuit of Britomart in the House of Ioue. It challenges her virgin and knight binary. For example, Britomart becomes Malecasta's target, when "still did she rove at her with crafty glaunce/ Of her false eies, that at her hart did ayme" (FQ III.i.50). In terms of Britomart's position, her vow of chastity becomes presented in Spenser's ambiguous spelling and sentence structure that aligns with her duality. It can be said the Malecasta has her "heart" set on Britomart, but it can also allude to how Britomart becomes the hunted "hart," which is, according to the Oxford English Dictionary, a wild stag that can be hunted. Depending on the interpretation of the word, Britomart can be perceived as a creature capable of sentimental emotion, or a fierce animal that must protect herself by any means necessary. Throughout the encounter between Malecasta and Britomart, the female knight assumes two positions: the delicate virgin (who focuses on the "heart"), and the ferocious slayer (who focuses on the "hart").

While Britomart's masculine characteristics overshadow her feminine ones, her devotion to chastity enunciates her womanhood and is further exaggerated by Malecasta's antithetical representation of "Bad Chastity," which is the literal translation of her name. Spenser dedicates a passage of Book III to articulate the characteristics of womanhood. He echoes the ubiquitous belief that Womanhood is best denoted when "to loue captiued are,/ And chaste desires do nourish in your mind,/ Let not her fault your sweet affections marre,/ Ne blot the bounty of all womankind" (FQ III.i.49). By associating womanhood with the virtue of chastity, stressing the difference between love and "sweet affections," Britomart becomes perceived as a perfect example of womanhood because she not only refutes Malecasta's overt seduction, but she also refuses to engage in any sexual activity until she marries. However, it becomes further reinforced when regarding the ideology of the Renaissance in terms of a female's sexual drive, perpetuating chastity as a feat over "female-specified" biology.

Due to Malecasta's exemplification of the lustful woman, she represents the image of the typical Renaissance female who was perceived as a biologically more lustful and less perfect representation of the Renaissance male. The circulating studies pertaining to the study of female physiology revolved around the notion that a female's reproductive organs were simply the result of a failed development while in the womb, resulting in "'an innate desire to achieve perfection by coupling with men'" (Mitchell, Osland 4). Britomart serves to perform the role of a woman who also identifies with male tendencies, while Malecasta submits to her "natural, biologically-engrained" lust by succumbing to her knight in shining armor. Her biologically-engrained lust overcomes her and provokes her desire to lie with Britomart. This spectrum enunciates the dichotomy between Britomart's and Malecasta's different representations of the expected image of the Renaissance's ideology of womanhood because Britomart remains chaste and disproves any proposition concerning sexual energy. Malecasta "was giuen all to fleshly

lust…So shamelesse beauty soone becomes a loathly sight" (FQ III.i.48) while Britomart is "'Mongst thousands good one wanton Dame to find:/ Emongst the Roses grow some wicked weeds" (FQ III.i.49). The binary relationship between Britomart and Malecasta emphasizes Britomart's image as the ideal woman, pronouncing her position as a female (according to Renaissance standards that wholly promote virginity as a symbol of desirable womanhood), while Malecasta serves to present the lustful antithesis who is undesirably frail in terms of protecting sexuality.

Although Britomart is associated with the identity of both a virgin and a knight, she allows the two to combine to fuel her character as a warrior that relies on her sexual energy to inspire her aggression. Her chastity provokes her success on the battlefield because she saves her sexual energy for Arthegall, the knight she pursues out of love, giving her incentive to battle. For example, when she flees the castle after the episode with Malecasta, Gardante shoots her with an arrow that "lightly rased her soft silken skin,/ That drops of purple bloud thereout did weepe,/ Which did her lilly smock staines of vermeil steepe" (FQ III.i.65). The allusion to a loss of virginity on the battlefield, assumed by the references to a white "lilly smock" (pure chastity) stained by "drops of purple bloud" (traditional bleeding alluding to the loss of a woman's virginity), evokes a correlation to Britomart's identity as a virgin knight who battles to retain her vow of chastity for Arthegall. The sexual correlation that revolves around Britomart's wound insinuates that the penetration from the fight relates to her virginal status and refers to her previous encounter with Malecasta who tried to steal her virginity from her. By adumbrating her potential loss of virginity with traditional symbolic imagery, Britomart becomes perceived as a woman warrior fighting to retain her image as Chastity. Overall, it becomes evident that her vow fuels her image as a knight because her sexual energy is harnessed to further promote her devotion to remaining a virgin—creating another medium for her two combating personas to converge and collide.

The duality that encompasses Edmund Spenser's *The Faerie Queene* arouses a tension that exists within the characters, the setting, and even the story itself. The main female protagonist, Britomart, epitomizes the notion of division that Spenser revolves his poem around, allowing this tension to take the shape of a character that manipulates the story itself. Her ambivalent identity regarding her gender and sexuality (revolving around her chastity) conflict with each other in extreme fashions, which do not only create extreme dichotomies, but also weave together to blend into a beautiful, warrior-like persona. When she encounters Malecasta, Britomart's character reveals itself as she battles her male and female traits, her aggressiveness and her delicateness, as well as her purity and impurity. As she leaves the House of Ioue on her noble steed with the Redcrosse Knight, "her bright armes about her body dight:/ For nothing would she lenger there be stayd,/ Where so loose life, and so ungentle trade,/ Was usd of knights and ladies seeming gent" (FQ III.i.67). She wipes the blood of Malecasta's massacred knights onto her armor nonchalantly, disapproves of the lack of gentleness and hospitality that she received as she sought shelter at the House, and continues forth on her journey as Spenser's image of duality. She voyages throughout the rest of the poetical work as the knight and lady, virgin and penetrator, and prey and hunter, carrying with her the ambivalence of her true

identity that fuels her existence, since all representations of her coalesce to create one of the gentlest yet most ferocious women in Renaissance literature.

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Bioremediation Mariculture in Zanzibar, Tanzania: A Viability Assessment of Using Bath Sponge and Pearl Oyster Farms to Filter Highly Polluted Waters in the Zanzibar Channel

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ABSTRACT

Bioremediation of polluted water off the coastline of the urban center of Zanzibar—Stone Town, Unguja—was assessed through bath sponge and pearl oyster mariculture feasibility. In recent years, scientific analysis has shown a wastewater pollution distribution in conjunction with the water circulation created by the East African Counter Current and its harmful ramifications for the fringing ecosystems. As a proposed mitigation to this issue and in following the experimental examples of bioremediation projects around the world, this study tested facets of the filtration abilities of marine sponges and oysters. Both organisms suggested strong pollution filtration abilities. Phosphate concentrations decreased from an average of 3.93 μg/L (micrograms per liter) to 1.33 and 1.73 μg/L for sponges and oysters, respectively. Unique capabilities of each organism were displayed in the experiments in that the marine sponges visibly eliminated the turbidity level in the 36-hour study period while the marine oysters were suggested to chemically convert the dissolved nitrates through the tested increase in ammonium concentration from an average of 4.01 μg/L in the contaminated water to an average replicate concentration of 21.5 μg/L. The respective mariculture techniques were examined along with management logistics to assess the viability of implementing mariculture for pollution remediation. It was concluded that the mariculture techniques could be feasibly established by carefully collaborating with the nature of the pollution distribution, the consultation and aid of private and governmental organizations and adjacent villages, and further background scientific research.

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1. INTRODUCTION

Polluted seawater is an undeniable and indisputable situation for active ports around the world. Stone Town, Zanzibar is an established World Heritage site where visitors from around the world come to see history, culture and biodiversity concentrated in one place, but it is also a polluted port that is further desecrated by the outflow of raw sewage pipelines and wastewater runoff directly into the waterfront. Numerous previous studies have shown that the sewage and wastewater runoff in the city of Stone Town have directly increased the concentrations of harmful nutrients and biological macromolecules along the town's coastline (Van Bruggen 1990, Anderson 1994, Shunula and Ngoile 1995, Mmochi 1996, Moynihan 2011), however, little has been done in the way of mitigating these pollutants. Unfortunately, most of this pollution comes from the stress of the ever-increasing population size of the urban center of Zanzibar. With this the outcome of Zanzibar's population growth must be managed to prevent any further damage to the health of both the surrounding ecosystems and communities. The cleanliness of the seawater proves essential to the habitability of the entire biosphere and must be addressed.

An extremely small proportion of industries and individual households are even connected to the sewage line, making runoff a substantial issue, especially in the rainy seasons (during which this study takes place). Wastewater runs off into the seawater along the coast, highly concentrated at the sewage outflows (Mmochi 1996), carrying water-borne illnesses and harmful toxins to coral reef and mangrove ecosystems, epicenters of ocean fertility and health, and the main source of livelihood for Zanzibaris. Controlling this disseminated source is seemingly unfeasible, but it can be remediated with an ecosystem-based (EBM) and integrated coastal-zone management approach (ICZM).

It is critical to act before this problem worsens. Luckily, there is still life in the ecosystems off of Stone Town, but with the continuance of such a prominent and unrelenting stressor, that life is not likely to remain. EBM and ICZM take into account the whole ecosystem affected and search for solutions to solve the entirety of the issue for the whole system (Mohammad, personal communication; *Progress in Integrated Coastal Management* 2000). In the case of this study, the mariculture also employs natural means of solving the problem. The proposed action for the mitigation of sewage-ridden water off of Stone Town, Zanzibar is zooremediation through bivalve molluscs and sponge porifera.

Zooremediation is progressively utilized as a solution to polluted waters all over the world, both marine and fresh, which employs organisms from various evolutionarily advanced positions, utilizing their natural biological processes to remediate contaminated water. Such species have varying abilities to filter, oxygenate and decontaminate the surrounding water column (Gifford et al 2006). Sponges and oysters coexist in the intertidal zone, the shallowest and most diverse ocean habitat, making them ideal filtration partners to holistically support that keystone ecosystem. Tangentially, working together allows that neither is overloaded while each contributes its unique individual abilities to aid humans in remediation of the damage continually done to the marine ecosystem.

The choice of these invertebrates arises from an expansive research base that has proven these seemingly evolutionarily simple creatures to be remarkable filter feeders, thriving off of what other species, including our own, process as biotoxins (Gifford et al 2005, Longo et al 2010, Rittschof and McClellan-Green 2005). These biotoxins consist both of the direct effluents and nutrients dissolved in the mixing of seawater and sewage such as nitrates, phosphate and ammonium, but also of phyto- and zooplankton and bacteria: the organisms in the water column that exist naturally to a certain extent but become over-populated and invasive with the introduction of high concentrations of these nutrients. High populations increase the turbidity of the water (amount of dissolved particles affecting the water's transparency), which prevents keystone-photosynthesizing organisms such as seagrass and algae (including the zooxanthallae algae in coral) from accessing the essential sunlight source. Bacteria blooms cause anoxic conditions in the water by depleting the dissolved oxygen in the water when metabolizing the accumulating nutrients. Consequentially, the seawater affected becomes highly noxious to the ecosystems contained, leading to entire 'dead zones' (*NOAA* 2013). The specific fauna in question for the remediation of these issues are bath sponges and pearl oysters, two organisms that naturally maintain the ocean's biochemical stability through filtering plankton and bacteria out of seawater.

Sponges and oysters similarly get their sustenance by sucking in ocean water, taking out microorganisms present, and spewing back out seawater rid of these components. Sponges in the phylum porifera have a specialized pore called the ostia that is able to draw in water through the action of many choanocytes, custom cells that pump water, creating a current in the surrounding fluid (Milanese et al 2003). This current pulls in the seawater surrounding the sponge containing bacteria, phytoplankton and zooplankton food sources, in addition to suspended particles, which is indiscriminately filtered through the animals' mesohyl matrices. These organisms have a uniquely strong retention and accumulation ability and can filter their entire surrounding water column in 24 hours (Longo et al, Gifford et al).

Similarly, oysters, which in the class of molluscs called bivalves, draw in water to filter through their stomachs and gills. This process, analogous to the sponges' choanocytes, is generated by cilium on the oysters' gill cells (Raj 2008). Their food source comes from microalgal nanoplankton, however, they are indiscriminate in filtering all particulate matter (Gifford et al 2005). Though they do take nutrients from the water column through their consumption of phytoplankton, they do release some as well (Saito 2012.) In this way, another bioaccumulator must be near to the oyster to have holistic biopollutant filter-feeding success.

Sponges and oysters are effective together because of their ability to collaborate in the filtration of most pollutants, but also to uniquely filter what the other cannot. Sponges are proposed as the nitrogen repository here to prevent the combination of edibility and wastewater filtration. In this way, sponges are proven to be highly effective at bioaccumulation of ammonia and their ability to accumulate dissolved biological particles at a high rate (Gifford et al 2006, Longo et al 2010), creating an ideal coexistence with oysters.

Neither organism, nor the ecosystems involved can tolerate overexposure to pollutants, and therefore a careful placement must be assessed to ensure adequate filtration of the pollutants without harming these animals or ecosystems. Variability in pollution concentrations can affect the abilities of the organisms to effectively filter (Souza et al 2013), so careful placement of the proposed mariculture will allow the organisms to effectively filter without vulnerability. Similarly, these organisms cannot become invasive to the ecosystems to which they are introduced, though management will be inherent given that these organisms are currently cultivated through mariculture practices around the island (Vauterlaus, personal communication; IMS), and that is the method proposed for implementation. Supervision and investment could be provided by the Department of Environment of the Revolutionary Government of Zanzibar. In this way, the use of pearl oysters and bath sponges to filter the water off of Zanzibar could be carefully designed to effectively aid in the port's pollution situation.

2. STUDY AREA

Farming methods are observed in the villages of Jambiani and Fumba, Unguja. The contaminated sample water is collected from Maruhubi, Unguja and the water off of the Institute of Marine Science. The 'clean' seawater is collected from Fumba, Unguja. The filtration techniques experiments and all water analyses were completed at the Institute of Marine Science, University of Dar Es Salaam, Zanzibar in Stone Town, Unguja. These locations can be found on the map of Unguja Island, Zanzibar in Appendix I, figure 3.

3. METHODS

The assessment of the viability and potential success of marine sponge and oyster farming for pollution filtration off of Stone Town is initiated through the observation of the individual farming methods in the respective locations they are practiced, observing the explants (the portion of harvested organism transferred to a new medium for growth). Then, the ability of the bath sponge and pearl oyster species are experimentally analyzed at the Institute of Marine Science laboratories. Finally, the logistical aspect of implementation is evaluated through managerial interviews.

3.1 FARMING AND ORGANISMS OBSERVATIONS

The shallow-water bath sponge farm in Jambiani is visited at a low, spring (wider range) tide by foot and snorkel gear. The mariculture apparatus, coexisting species/habitats, and maintenance methods are observed. Local community members are surveyed on their opinions of the mariculture potential, including another MC employee. [Employees remain anonymous.]

The oyster farm in Fumba is observed by boat, using snorkel and free diving techniques with the farmer. Regular maintenance and cultivation processes are observed. Coexisting organisms and adjacent habitats are observed and recorded. The farmer is asked how he collects explants,

about the process of growth and cultivation, and about the market. Local community members are surveyed on their opinions of the mariculture practice.

3.2 COLLECTION

An extremely sharp knife is used to harvest one third of the animal's body volume. (Duckworth et al 2007.) Four species most commonly occurring on the Jambiani intertidal are collected: the 'grey', 'green', 'red-branching', and 'black' species. The sponges are never squeezed given that this may be harmful or even fatal to the organism and its functions. The collected explants are always covered in seawater, and immediately transferred to an oxygenated storage tank upon arrival at the laboratory.

Pearl oysters are collected at a morning spring low tide in Fumba, Unguja. The animals are collected by gently pulling them off the hard surface to which they are attached. A minimum of thirty oysters is needed for the six sample buckets. The oysters are transported in a mesh bag out of water, but immediately transferred to six oxygenated storage buckets.

'Control' seawater is collected from Fumba, Unguja using a large 20-liter bucket. Contaminated seawater is collected from the beach in front of Marahubi ruins, a focal location determined by the Zanzibar Channel current discussion (see Appendix I, figure 3).

3.3 FILTRATION ABILITIES

The filtration abilities of the sponges are assessed using the collected sponges from the Jambiani intertidal. The sample specimens are given 36 hours to filter the experimental water column; nothing is added or taken out during the experiment period except oxygenation. The four sponges are placed in a 20-liter bucket filled with 15 liters of contaminated water. During the experiment period, turbidity and particle observations are made at four even intervals.

Oysters are individually able to filter 2 gallons, or about 8 liters of water per hour (Raj 2008) providing that five oysters should effectively filter 2 liters in one hour. Five oysters are placed in each of six 15-liter buckets containing 2 liters of contaminated seawater each. The first five sample oysters are then placed in the sample bucket and a one-hour timer is started. Three sample buckets are run at the same time using this method, therefore repeating the above method two times (for six samples). Observations of the filtration and other activities of the oysters are taken during the sampling period, including the turbidity and movement patterns of the water. After the one-hour trial, the oysters are placed back in their oxygenated holding buckets and the sample water is poured into the respective labeled water bottles.

A 0.5-liter sample of each of the 'contaminated' seawater from Maruhubi and the 'clean' seawater from Fumba are taken. These samples and the trials described above are stored in collection bottles in a -20^{oC} freezer until they are tested for phosphates and ammonia using a spectrophotometer. These methods are dictated in Parsons et al in the *Manual for Seawater Analysis* (using the 'alternative' method for ammonium).

3.3 MANAGEMENT LOGISITCS

The implementation of *Marine Cultures* on Unguja by resident Christian Vauterlaus is analyzed. The logistics of implementation and why he chose Jambiani as a location are inquired. The market for the sponges and economic details are investigated. Finally, the rapport with the local community, how it is kept and what the steps are for future cooperation are explored.

Hamza Rijaal is the representative respondent for the Zanzibar Department of Environment. The zonation of Stone Town in terms of the plans for the sewage and drainage systems is investigated along with the potential for the Department to aid the project.

4. RESULTS

4.1 FARMING TECHNIQUES AND BIODIVERSITY

The experimental shallow-water sponge farming project in Jambiani, Unguja was analyzed and observed for 4 days. Interviews of the employees and local community members displayed a great interest in the new form of mariculture recently introduced (2008-9) to the small community. The shallow-water farm itself (one of three currently operated by *Marine Cultures* in the area) was exposed at about 1 meter at low tide (between a spring and neap low tides). It consisted of a 6x6 meter rope system with rows of sponge explants (diagram in Appendix I, figure 6). A high biodiversity of coexisting organisms was evident surrounding the farm. The employees interviewed indicated that the farming was relatively easy and low-maintenance (given the accessibility and tools described above).

A pearl oyster farm at Fumba, Unguja was visited. The farm belongs to a single man who created, cultivates and monitors the farm independently (with the aid of IMS—Jiddawi, personal communication). The farm was accessed by dugout canoe and at a neap low tide the farm was at a depth of 4 meters, reaching 6 meters at a spring high tide. The maintenance of the farm involves checking small pieces of wood or plastic, designed for growing new explants, attached to the main T-shaped line (sketch of farm in Appendix I, figure 7), looking for new explants growing along the main line and transferring them to the mesh baskets, and taking the mesh baskets to the surface to clean off the biofouling, clean out the basket of any trapped or biofouling organisms, check on the growth of young oysters, and clean each oyster. A metal prying tool was used to slightly open the shell without damaging the animal to check on the status of the pearls. High biodiversity of coexisting organisms was evident surrounding the farm.

When asked about the cultivation process, the farmer explained that he gets the oyster explants from a deep reef about 1 km southwest of the farm and about 15 meters in depth. He explained that there are many oysters at the reef of different species; displaying the two types he grows, which were later identified as *Pinctada fucata* and *Pinctada radiata*, the former being more abundant and common in Zanzibar. In response to oyster growth, the farmer explained that it takes a year and a half to grow to maturity and to propagate all four pearls [Farmer to

remain anonymous]. In the local village, community members responded that they appreciate the income source of pearl farming and the ease of using the employment as a supplement in the local economy.

4.2 COLLECTION LOGISTICS

The collection of the seawater samples was partially restricted by the access to transportation and resources for water transport. Containers for seawater collection were small and previously used, possibly leading to partial contamination of the samples. Both organisms were collected at a significant distance from Stone Town (the testing and storage site). Both organisms were easily collected at the respective sites, minimally disturbed, and stored in spacious, oxygenated conditions at the lab.

4.3 FILTRATION ABILITIES

The tank containing the sponges was significantly turbid prior to sponge implementation and was relatively transparent by the end of the study. The water in the experimental bucket appeared to be flowing based on the visible movement of the particles towards the sponges, but not discernibly circulating.

The water surrounding the oysters became less turbid over the hour-long filtration period. After 5-7 minutes, all oysters in all trials had opened their shells and were actively filtering. The size of the oysters varied between 5 to 10 cm in diameter and the degree of shell opening and valve exposure varied between 0.2 to 1.5 cm.

The spectrophotometer tests displayed that for both the sponges and the oysters, the concentration of phosphates decreased significantly (see figure 1). The average concentration of the contaminated water replicates was 3.93 μg/L phosphate (before filtration). After the sponge filtration period, the average phosphate concentration of the sample seawater was 1.33 μg/L. Similarly, the oysters decreased the concentration to an average of 1.73 μg/L phosphate. The control seawater sample from Fumba contained 1.86 μg/L phosphate.

The side channel itself is approximately 400 meters long and 20 to 30 meters wide. It includes of a mixture of riffles, pools, and glides. The U.S. Forest Service placed five log jams throughout the side channel (Figure 1, Bonanno et al. 2011). The side channel section remains around 6 degrees Celsius for most of the year and can increase to 16 degrees Celsius during summer months, making it optimal spawning ground and rearing habitat for spring Chinook salmon, bull trout (*Salvelinus confluentus)*, and many other aquatic species and wildlife native to the watershed (Risley et al. 2010).

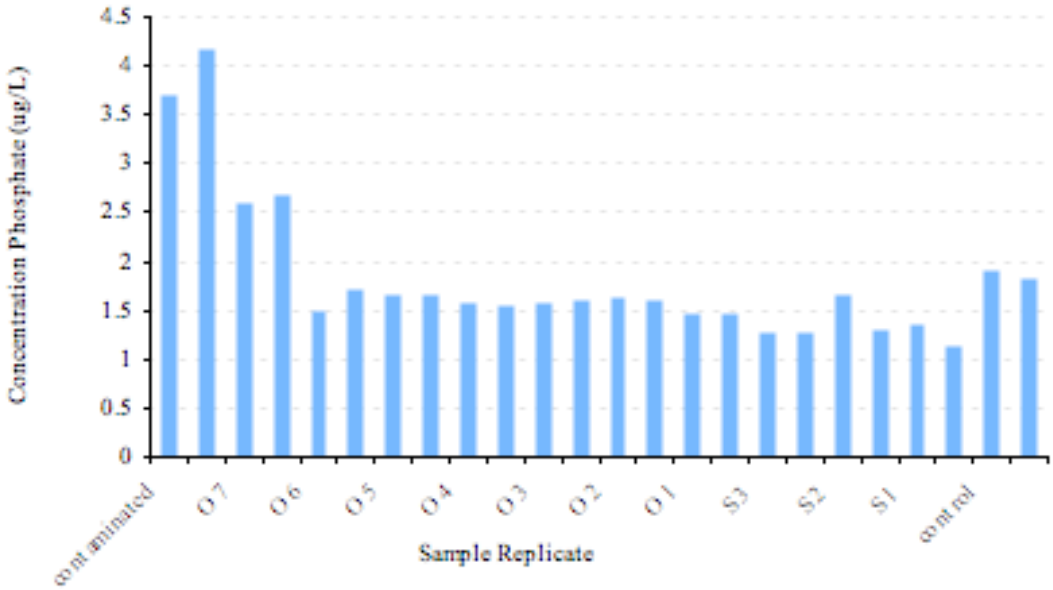

Figure 1. Experimental Phosphate Filtration Results (O=oyster; S=sponge.)

For the ammonium test, (only completed for the oyster samples), the concentration of ammonium increased during the filtration period (see figure 2). The average ammonium concentration of the contaminated water was 4.01 μg/L and went up to an average of 21.5 μg/L after the sample filtration period.

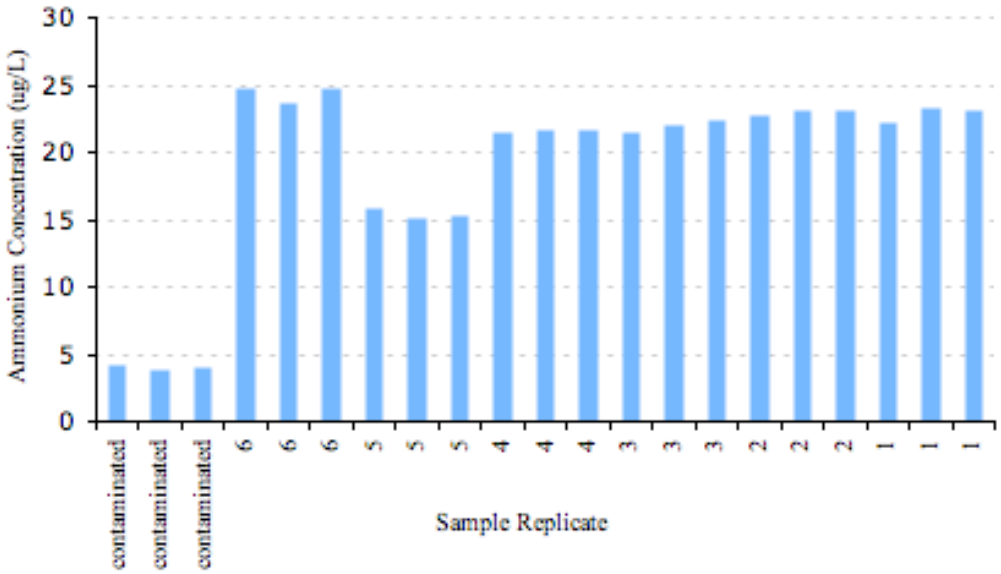

Figure 2. Experimental Oyster Ammonium Filtration Results

4.4 MANAGEMENT INTERVIEWS

Christian Vauterlaus the founder of the Zanzibar branch of *Marine Cultures* (Vauterlaus, personal communication). After a trip to the South Pacific to study alternative tropical mariculture options, *Marine Cultures* found a sponge-farming project in Micronesia that had been successful for a highly impoverished place (similar to Zanzibar). Vauterlaus explains that the farming is relatively easy to implement, manage, and sell on a rising world market. Ultimately, *Marine Cultures* feel they have a connected and successful relationship with the local community. In terms of future prospects, Vauterlaus indicates that after logistics are figured out, *Marine Cultures* plans to aid locals, other organizations, and government institutions in starting the mariculture where it is wanted and needed, in addition to continuing research on controlling and regulating the growth.

Hamza Rijaal was the respondent for the interview of the Zanzibar Department of Environment position on remediation efforts. He referred to the Zanzibar Environmental Policy created in 1996, which dictates that the department's role is to identify an environmental issue and suggest solutions or alternatives. In explaining the current sewage situation it was revealed that only the originally defined perimeter of Stone Town is a part of the sewage pipe system (see Appendix I, figure 5 map). He explained that the outflow pipes used to go only 10-50 meters off shore, then changed to 150-200 meters with the discovery of high effluent concentrations. The original decision for this system was that the Eastern Africa Counter Current (EACC) would be strong enough to take the polluted water away from human habitation, also creating mixing, and therefore not harm the marine environment to a great extent. He disclosed that this system is not working to keep the harmful effluents from the coast and that the effects are evident at the offshore reefs. Rijaal disclosed that the system often fails when sewage overflows into the streets and becomes runoff, particularly in the rainy season. Similarly, the expanding population is not on this system, but has individual tanks or simply buries the waste. Both of these methods routinely overflow and leak raw sewage and effluents into the runoff onto Unguja's coastline. When asked about the department's role in environmental remediation, he mentioned the Van Bruggen study completed in 1990, which was one of the department's first actions. Upon further prompting, Rijaal indicated that the department is open to aid new projects for remediation of environmental issues.

5. DISCUSSION

5.1 POLLUTION SITUATION

The growing human population in Stone Town, Unguja undeniably affects the surrounding coastal waters destructively. A large population places significant pressure on the adjacent ecosystems not only through resource use and extraction, but also considerably from the waste associated with resource use. Stone Town's leading issue, both for the health of the ecosystems and the human population, is the effluent pollution leaking straight from sewage and runoff outfalls. A majority of the population is not a part of the sewage system and therefore either have their own tanks or no system at all (Rijaal, personal communication). These systems leak

into the groundwater and overflow during floods. The sewage treatment that is present in the city only involves the originally defined area of Stone Town (west of Mkapa Road—see Appendix I map, figure 5). This system directs wastewater into a septic tank, through a salt pit and then through out-flowing pipes straight into the coastal water. Unconventional systems are usually just dug pits, which seep the nutrients directly into the groundwater. Even connected to the sewage lines, all of these systems described cause leakage of raw sewage effluents into the watershed, which on a small island such as Zanzibar is directly into the seawater.

Stone Town's population is constantly growing as people come for the opportunities associated with the city, which yields growing pressure on the minimal wastewater plan that exists. The initial decision to allow raw sewage and wastewater to flow directly into the coastal seawater came from the belief that the EACC would solve the problem of pollution. However, the shallow nature of the Zanzibar Channel greatly slows down the strength of the EACC, nullifying its power in transferring and mixing the seawater (Nyandwi, personal communication). The outward jut of Stone Town toward the west creates a slight deflection of the current to the northwest. This detail would perhaps effectively take the hazardous water directly to the deeper portion of the Channel allowing for adequate mixing, but the fringing islands off Unguja's southwest coast complicate the matter. While there is a flow of the current directly northwest, the destination is directly between two of the fringing islands, funneling much of the seawater through the opening (called the 'Great Pass' locally), but deflecting much of the seawater back to Stone Town and the adjacent coastline (see Appendix I, figure 4 schematic, Anderson 1994). Subsequently, the contaminated seawater that is not sufficiently mixed carries harmful nutrients to the coral reef ecosystems of these fringing islands, and back to the human population of the coastline.

The harmful nutrients and effluents include nitrates and phosphates, which facilitate the growth of bacteria and phytoplankton algae. Particularly, nitrogen facilitates the growth of bacteria, which live in the sediment and water column, acting as natural nitrogen fixers for the soil and atmosphere. Although this allows for the growth of the mangrove trees, which obtain their oxygen source from the atmosphere, it creates oxygen-depleted conditions in the surrounding seawater, prohibiting the inhabitance of most marine organisms. Similarly, phytoplanktons thrive off of the phosphate source for growth. The experimental value of 3.93 μg/L phosphate is high in comparison to the naturally occurring concentration in seawater (Intergovernmental Oceanographic Commission 1993), which is an indication that these nutrients are introduced from an outside source (Parsons et al 1985). This yields an increase in the phytoplankton population and sequentially the zooplankton population, increasing the turbidity of the water (called a 'bloom') and decreasing light access to keystone photosynthesizing organisms, such as the zooxanthallae algae of coral and sea grasses. Consequentially, the upsurge in bacteria and phytoplankton from the excess concentration of nitrates and phosphates, respectively, in the seawater is deleterious to the corresponding ecosystems.

Polluted seawater carries the dissolved nutrients discussed, increasing populations of marine microorganisms as well as the effluents associated with sewage, such as fecal bacteria.

These bacteria include fecal coliforms (*Enterococci* and *E. coli I*), which, dissolved in seawater, can be both an indication of sewage runoff presence (Hanes and Fragala 1967), and can be extremely dangerous to the health of the human population and the ecosystems. A study completed in 2011 to test indications of sewage in the coastal seawater off of Stone Town suggested that there were high concentrations of the bacteria in the water. What was particularly pivotal was the discovery that the concentrations were highest near the outfalls, but were also found on the fringing reefs of Stone Town, such as Bawe and Chapwani (Moynihan 2011). The study additionally shows that the bacteria present are correlated with early stages of eutrophication. It is therefore evident that the sewage runoff is not only reaching the surrounding ecosystems, but also starting to damage them as well.

The turbidity of the seawater observed throughout the study is an indication of these microorganisms and effluent particles present. In the collection of contaminated seawater at Maruhubi, the seawater was highly turbid with a sight distance of less than 1 meter. As reported in the results, this sample water was still distinctly turbid prior to the filtration experiment, indicating that the turbidity of the water in the collection site was not simply due to sediment, as may have been assumed given the collection time at low tide. Suspended particles were observably filtered throughout the experimental interval, however, a total suspended organic carbon analysis could not be completed because of the observation of suspended organisms that would not be filtered and would skew the results, such as barnacle bodies. Nonetheless, the observation was deemed viable in suggesting that most of the suspended material was microorganisms, such as the bacteria and plankton discussed.

The Zanzibar Institute of Marine Science, located in the heart of the area in question, is constantly working to research both the progressing effects on the environment and the potential solutions. However, the previous bioremediation solutions (sea cucumber and algae) have had little success, probably because of the traffic in the area and the strong concentration of pollutants (Jiddawi, personal communication). Perhaps adjusting the placement of the experimental remediation would aid in its success, such as a location far enough down-current from the pollution source to prevent overloading the filtration system, but before the water can reach the vital coral and mangrove ecosystems or the feedback eddy system. Optimizing the location in this way aids in both the protection of the physical structure of the system and the survival of the filtration organisms involved.

5.2 FILTER-FEEDING CAPABILITIES

The abilities of oyster bivalves and sponge porifera, powerful filter feeding animals, have been analyzed and explored. Sponges are evolutionarily simple organisms yet they greatly contribute to their ecosystems through the filtration of the water column. This is possible because the ostia pores throughout the body have the ability to filter all particles between 0.1 and 50 micrometers, which provides them the nutrition of phytoplankton and bacteria (Friday 2011). Through this process they accumulate the water's nutrients that these lower-trophic-level microorganisms concentrate in their cells. A particularly important note about the filtration abilities of the sponges is their uniquely high retention rates, which is suggested as up to 80% of

the particles they filter (Milanese et al 2003). This presents how incredibly essential sponges are to their ecosystems in retaining the harmful particles to other species as sustenance for their own growth.

The collected sponges of this study proved to be effective filtration systems for the experimental water column. The analysis of phosphate displayed a decrease in the concentration over the study period from 3.93 μg/L of the contaminated sample seawater to 1.33 μg/L (average concentration) of the water after the sponges' filtration period (see figure 1 in section *4.3 b*). This demonstrates that the sponges are successfully accumulating the phosphate source in the seawater, most likely from the thriving phytoplankton populations. In a study comparing the phosphorus and nitrogen levels with the phytoplankton and bacterioplankton present, a correlation between phosphorus and phytoplankton levels was evident, and a further relationship between phytoplankton and bacterioplankton was present as well (as the bacterioplankton consume the phytoplankton), indicating that an increase in phosphorus levels increases phytoplankton and bacterioplankton correspondingly (Kisand et al 2001). As discussed in section *5.1*, an increase in these microorganisms can be incredibly harmful to the coinciding habitat and marine environment.

A perhaps even more pivotal observation in the study is the elimination of water turbidity and particle evidence. This suggests that the organisms are not only taking the harmful chemicals out of the water, but also the harmful bacteria and plankton that are thriving off of the chemicals. Tropical Demosponges, such as the proposed species, feed off of microorganisms, organic particulates and bacterioplankton (Holmes 2000), which cause turbidity in the water and threaten the ability of the photosynthesizing organisms such as seagrass and coralline algae to photosynthesize and oxygenate the seawater, which is an imperative ecosystem service. When the sponges and oysters filter the water of these destructive microbes, they are thereby indirectly assisting marine photosynthesis. A European study completed in 2006 concluded that in one hour a 1-m^2 patch of sponges could retain up to 7×10^{10} *E. coli* cells through a filtration of 14 liters of seawater (Gifford et al 2006). *E. coli* are bacteria cells that are contained directly in the effluent runoff and can be deadly to humans if ingested, not to mention the damage done to other consuming species. It has been found that, in some places, benthic sponges may even thrive closer to an enrichment source (Holmes 2000). The idea that sponges can filter and retain these cells proves them to be vital to a remediation process for both humans and the surrounding impacted ecosystems.

Fortunately, marine sponges are abundant and highly diverse around Zanzibar. The species under investigation is in the class Demospongiae, which is highly adaptable, proven through the observation of their ability to regenerate their pinacocyte (analogous to epidermis) tissue after explantation and continue to expand their mass and volume of each explant, all from the same original organism. This was evident in both the observations of the farmed sponges and the collected sponges of Jambiani, Unguja. Sponges collected for the filtration experiment had covered the spongocoels and choanocytes (inner anatomy exposed from cutting) with pinacocytes by the second day of study. These examples display their adaptability to

morphological manipulation and therefore their ability to successfully survive and grow throughout explantation.

Similarly to sponges, oysters provide an ecosystem service to their benthic habitats through filtering the surrounding water column. Oysters are mollusc invertebrates that obtain nutrition from oxygenated seawater as it is delivered to their gills. Both *P. fuctata* and *P. radiata* species suggest that oysters feed nonselectively, meaning through the filtration of seawater for a microalgal food source, the species filter the entire surrounding water column of particulate matter (Gervis and Sims 1992). Another study performed in Australia on *P. imbricate* indicated that one ton of oysters could filter 7.5 kg of nitrogen and 0.55 kg phosphorus (Gifford et al 2005). Such findings are strong representations of the power oysters have in seawater nutrient remediation, particularly in large populations.

The filtration experiment supports this data in showing the significant decrease in phosphate concentration of the seawater samples after the filtration periods. In comparison to the 3.93 μg/L phosphate concentration of the contaminated water, the average concentration after oyster filtration of the seven replicates was 1.73 μg/L (see figure 1 in section *4.3 b*). Similarly to the sponge, this indicates the effective uptake of the destructive phytoplankton population in the seawater, and therefore the pivotal ecosystem service the oysters provide.

As indicated in the Australian study, the oysters are also distinguished accumulators and curators of nitrogen levels. The sharp increase in the concentration of the ammonium dissolved in the seawater is an indication of dissolved nitrate remediation and eutrophication prevention. The average ammonium concentration in the contaminated seawater is 4.01 μg/L while the average concentration after the filtration experiment is 21.5 μg/L. This sharp increase is suggested to be caused by the remediation of nitrates given that dissolved nitrogen exists in seawater in one of the two forms. With the acute increase in ammonium concentration across replicates (see figure 2, section *4.3 b*), the oysters are evidently accumulating the nitrates in the seawater and releasing the source as ammonium to a dominant degree. Oysters contain symbiotic bacteria in their gills that perform this denitrification, providing the oysters with the oxygen gas byproduct (Raj 2008). Accordingly, the oysters actually need a certain concentration of nitrates in the water and therefore it is advantageous to the organisms to out-compete the sediment bacteria (highly concentrated in mangrove stands) for the nitrogen source, thereby indirectly preventing that anoxic process. While the surge in ammonium concentrations are admittedly not much more ideal for the aquatic environment, the substance can at least be treated by a simpler organism. The project by Lindell in the United States utilizes the high concentrations of ammonium to grow seaweed near the oyster farms (Saito 2012). Thus it could be advantageous to continue this study by including seaweed as a tertiary remediation source, which would contribute further to the idea of a holistic ecosystem-based management approach. Ultimately, oysters are suggested as uniquely effective nitrate remediation for polluted seawater filtration.

While the sponges are unique in the strength of their dissolved particle retention, oysters have some retention ability as well. The study completed in 2006 for the journal *Trends in*

Biotechnology supports these findings, showing both that oysters reduced effluent presence of nitrogen and phosphorus (by 72% and 86% respectively,) but also the turbidity due to chlorophyll a concentrations (Gifford et al 2006). Chlorophyll a is what accumulates when microalgae and bacteria overpopulate, disallowing photosynthesizing organisms to use the compound for energetic processes. The turbidity remediation by both the sponges and the oysters studied could have been more effectively quantified with a total dissolved organic carbon test. However, due to lack of time and lab resources, the test could not be completed in the study period. This obstacle was overcome using simple visual observation, permitted by the incredible filtration abilities of the two organisms.

5.3 MARICULTURE FEASIBILITY AND IMPLEMENTATION LOGISTICS

The filtration abilities of both the sponges and the oysters are clear and indispensable, and the idea that they can be farmed could provide incentive for implementation. The mariculture farming practices of both bath sponges and pearl oysters require regular maintenance and monitoring, but comparatively inexpensive and uncomplicated supplies with accessible near-shore locations. Advantageously, both methods require similar supplies, which can be made and sold locally, adding even more of an economic stimulus from the two mariculture implementations. In the same way, the market for the products must be accessible to the local populations for the farming techniques to be practical. The organisms of this study were not only chosen because of their premier filtering skills with an economic incentive provided to local communities, but also decisively because they are not cultivated for consumption purposes. In spite of this precaution, the organisms must be prudently processed to prevent reintroducing the same pollutants they filtered in the first place. A novel Japanese bivalve farm created a process for removing cadmium from the mollusc meat where the cadmium is recycled and reused by a car battery plant to make fertilizer (Gifford et al 2006). This progressive innovation for the waste material is a representation of the further research that is needed regarding the proper disposal or further remediation of the polluted waste from these proposed cultivation techniques. Both farming techniques provide a significant economic stimulant to the local community on multiple levels, and that is an extremely important aspect in the consideration of implementing a new project in Zanzibar.

With progressing pollution issues, immediate action is necessary to prevent any further damage to the human habitation and marine life of Zanzibar's coastline. Through the study of the pollution situation, the proposed organisms' filtration abilities, and the cultivation logistics it is evident that the implementation of these systems could actually be possible with proper management and organization. The proposed techniques are supported by the definitions of ecosystem-based management and integrated coastal zone management, which are both viable strategies for environmental planning and policy. From the study of *Marine Cultures* and the interview with Christian Vauterlaus it is apparent that the experimental sponge mariculture is progressing successfully and has great potential for the village of Jambiani.

The study of the Department of Environment's involvement with pollution remediation efforts provided an insight into the steps for the proposed implementation. In conjunction with

the environmental policy of 1996, it is evident that the department is not particularly involved in the creation of policy, but is active in identifying environmental stressors and proposing solutions. The National Environmental Policy for Zanzibar (1996) states that Integrated Coastal-Zone Management should be used as a framework, and that efforts should pay particular attention to pollution degradation to coral reefs and mangrove stands. It also emphasizes community participation in environmental management, and asserts that environmental legislation should be drafted in support of pollution control and environmental health. By these standards, the proposed project is the ideal primary solution to the pollution situation given that it is taking an integrated approach through a holistic ecosystem viewpoint directly involving and benefiting the local community. Implementing bath sponge and pearl oyster farming for the remediation of polluted waters could be promoted and aided by the Department of Environment through further community outreach and education, legislation enactment, and funding opportunities. Ecosystem-based management is a format for handling environmental issues which calls attention to the entire system: what is taken out, what is put in, and the indirect services the system provides (Mohammad, personal communication), which is appropriate for the implementation of the bath sponge and pearl oyster filtration mariculture given the fact that the proposed remediation techniques treat the pollution using a natural member of the ecosystem. EBM highlights the connectivity within ecosystems, between ecosystems, and with the human population.

With a hypothetical implementation of the proposed techniques, the location is a pivotal aspect, which indicates that the shores of Maruhubi and/or Mtoni are prime locations for remediation. Seawater at this location is far enough away from both the traffic of Stone Town and the intensity of sewage outflows (see figure 5, Van Bruggen map, of Appendix I). The formation of this coastline is also ideal because its shallow depth allows access to the community to the potential locations of the mariculture farms. The seawater deflected off the Stone Town peninsula would pass through these actively filtering waters before reaching the fringing reefs or the feedback water circulation system (see diagram in figure 4 of Appendix I). These logistics are vital considerations in the implementation of the mariculture for pollution remediation.

6. CONCLUSION AND FUTURE RECOMMENDATIONS

Bath sponge and pearl oyster farms are suggested as feasible natural pollution filtration systems for the remediation of the seawater off the coast of Stone Town, Unguja. These coastal waters have displayed high concentrations of pollution since investigation began in the 1990s. With a lack of proper planning for the runoff system in the growing urban center, raw effluents have been consistently discharging into the coastal seawater since the city's emergence, gaining strength with the surge in population in recent decades, and noticeably impacting the fringing keystone coral reef and mangrove ecosystems along with human populations. Raw effluents carry dissolved nutrients, such as nitrates and phosphates, toxic microorganisms, such as fecal coliform bacteria, and dissolved organic compounds. The nutrients cause overpopulation of naturally occurring microorganisms in the water column, which creates inhabitable conditions

for other organisms. The fecal bacteria can carry deadly diseases to the human populations and can be toxic and deleterious to the species in the affected ecosystems.

Detrimental affects of pollution strongly advocate for the establishment of techniques to decelerate the environmental degradation. This study displayed a glimpse into the unique filter feeding abilities of the powerful marine sponges and oysters, displaying phosphate accumulation and indicating filtration of phytoplankton overpopulation. Marine sponges exhibited a unique ability to retain suspended particulate matter through the turbidity observations, while the oyster analysis suggested a unique ability to remediate nitrate levels through chemical transformation, both of which are supported by literature. This proposal is in extremely theoretical and experimental stages so for responsible and effective implementation of the proposed techniques, further research needs to be completed. In terms of the filtration abilities of the organisms studied, nitrate and dissolved oxygen analyses would further support the data on their ability to effectively filter the pollution. Additionally, varying concentrations of the contaminated seawater in relation to the organism replicate filtration rate/quality would indicate the organisms' tolerance to pollution levels.

In conjunction with the filtration abilities of the organisms, the research on the farming accessibility on the island of Zanzibar suggests that implementing the mariculture as a pollution filtration system could be highly effective. Collaboration would be highly effective to initiate the remediation, including the consultation by the organizations that are already experimentally practicing the farming techniques around the island, the management and aid of the applicable governmental sectors, the education and participation of local communities, and the continuance of scientific research by the Zanzibar Institute of Marine Science. A key future study, however, would be the contaminant level of the living tissue that is disposed of after cultivation and techniques to recycle or neutralize these potential waste products.

Implementing ecosystem-based filtration techniques for the remediation of polluted seawater off the coast of Stone Town is a prudent action in protecting the health of the human population and the environment. The techniques would not only benefit the ecosystem by catching the toxic water before it enters the ecosystems, but also before it enters the feedback water circulation eddies, bringing the pollution back to the surrounding coastal inhabitance. With further research, the proposed project has the ability to benefit the environment and the human population simultaneously, while slowing the harmful effects of the pollution inputs.

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APPENDIX

Figure 3. Zanzibar Ungujaa Island with study area markers. (GoogleEarth, 2013)

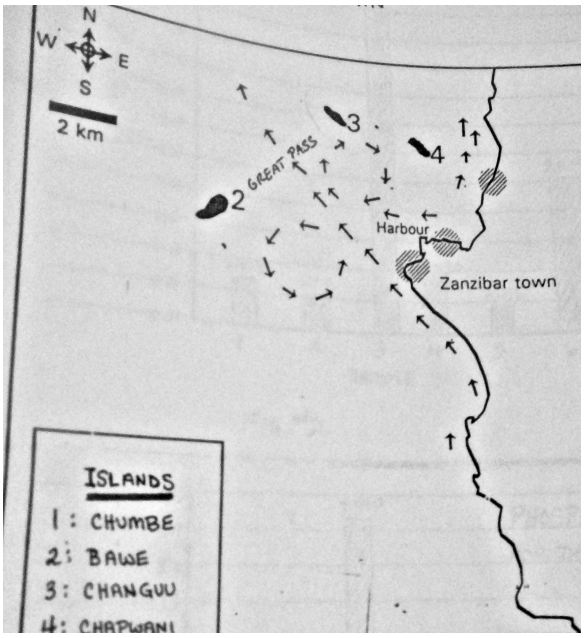

Figure 4. Urban Zanzibar seawater current system (Anderson: 1994).

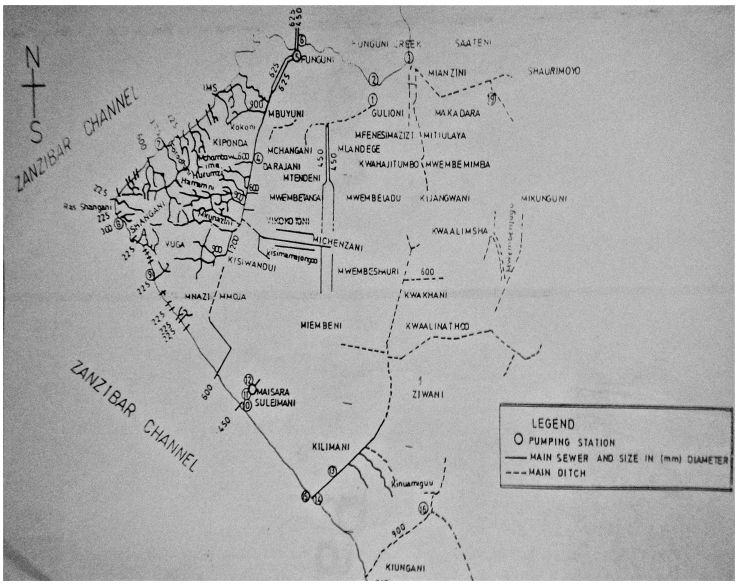

Figure 5. Stone Town runoff system. (Van Bruggen 1990).