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A LOOK INTO MILLSTONE NUCLEAR POWER PLANT: ATTITUDES ON
SUSTAINABILITY AND PREVALENCE OF EPIZOOTIC SHELL DISEASE

by

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A Thesis Submitted in Partial Fulfillment
of the Requirements for a Degree with Honors
(Marine Science)

The Honors College

University of Maine

May 2018

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ABSTRACT

Epizootic Shell Disease in *Homarus americanus*

American lobster populations along the northeastern U.S. coast have been experiencing increased prevalence of Epizootic Shell Disease (ESD) over the past two decades. Several reports have correlated this increase with warmer water temperatures. My thesis examined the distribution of diseased lobsters surrounding Millstone Nuclear Power Station (MPS) in Long Island Sound. Lobsters in this area have seen a rise in Epizootic Shell Disease (ESD) that parallels the broader trends. To determine if the thermal plume from MPS had a local effect on ESD prevalence, the spatial distribution of diseased lobsters was analyzed at three stations Twotree, Jordan Cove, and Intake, using data from 1984-2016. No statistically significant relationship was found between average bottom water temperature and shell disease prevalence per station. Twotree, the most offshore station with the coolest bottom water temperatures had the highest prevalence of shell disease. In contrast, prevalence at this station was due to a higher frequency of diseased females in the population. It has been hypothesized that lobsters with ESD have compromised immune systems. The immune system of lobsters relies primarily on the phagocytic activity of hemocytes within their hemolymph. I examined hemocyte abundance in 18 lobsters sampled in 2017 and found that lobsters with intermediate stages of shell disease had the highest hemocyte counts.

The Nuclear Industry's Concepts on Sustainability

How do we understand the role of nuclear power generation in a sustainable future? Is this low-greenhouse gas producing energy source part of that future? In my second study,

I addressed these questions by conducting qualitative, semi-structured interviews with employees of MPS, a nuclear power plant owned by Dominion Energy. The purpose of this study was to understand the attitudes *of people working within a nuclear power plant* towards sustainability and nuclear power. The results indicated that employees have a more economic view of sustainability and that nuclear energy is viewed as transitional fuel source. These responses were congruent with concepts found in the literature and should be taken into account from when creating policies regarding renewable energy.

ACKNOWLEDGEMENTS

As it takes a village to raise a baby, it takes a similar village of different skills and talents to help an undergraduate go from idea, to proposal to project, to writing, to defense. I would like to take this time to thank everyone who has helped me on this journey.

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CHAPTER ONE

INTRODUCTION

In 1999 the American lobster population of Long Island Sound suffered a significant mortality event (Pearce and Balcom 2005). This mortality event was observed as a steep decline in abundance measured by total catch, where in some regions catch declined as much as 99% from the previous year. The root cause of the mortality event was the amoeba *Neoparamoeba pemaquide*. This species of amoeba attacks the nervous tissue and leads to death in *Homarus americanus* (Pearce and Balcom 2005). While *Neoparamoeba pemaquide* was the main cause of death, the American lobster population in 1999 was also experiencing other stressors. For example, in 1999 the average bottom water temperature in Long Island Sound was 21°C and exceeded 23.5°C in some cases. Stress degree days for American Lobsters are defined as days when the water temperature exceeds 20°C. There was a total of 83 stress degree days for 1999. That year was also the first year that city of New York had an outbreak of West Nile Virus and used the pesticide malathion to combat the outbreak. Malathion is an insecticide targeting mosquito larvae carrying West Nile Virus. It was sprayed as a ground aerosol in many New York neighborhoods from 1999-2000 (Karpati 2004). Although laboratory tests indicated concentrations of the pesticide in Long Island Sound were too low to cause the mortality event in lobster, the pesticides may still have impacted American lobsters immunocompetence (Pearce and Balcom 2005). At the same time of this mortality event American lobster populations were also seeing a rise in epizootic shell disease (ESD).

Increases in ESD have been attributed to multiple stressors in the environment, but particularly temperature. My research investigates if the thermal effluent from Millstone Nuclear Power Plant exacerbates or contributes to ESD in American lobster populations around the plant.

Millstone Power Station (MPS) currently consists of two pressurized water reactors, Unit 2 and Unit 3. These reactors use a once-through cooling system that takes in water from Niantic Bay at the depth of 4.6-7.6 m from mean sea level. The intake flows at Unit 2 and Unit 3 (36.1 m³/sec and 59.8 m³/sec, respectively; MPS Annual Report 2015) are high enough to drain Niantic Bay in less than two weeks if the water was not returned to the bay (Don Landers, pers. comm.). In 2016, MPS used 89% of the permitted cooling water volume. MPS is permitted to discharge seawater that has been heated to a maximum of 32°F (17.8°C) above ambient temperatures. During 2016, temperature in the discharge seawater from Units 2 and 3 were 23.7°F (13.2°C) and 15.6°F (8.7°C), respectively (MPS Annual Report 2015). The resulting thermal plume is on average 10.5° C warmer than the ambient water temperature, which was well below permit limits. In addition, the water is discharged directly into an abandoned granite quarry that has a 3.5 ha surface area and a maximum depth of 30m. A numerical model by Adams (2001), suggests that the water exiting the quarry increases temperature at neighboring Jordan Cove, by 8°F, while the temperature at Twotree Island only increases by 1.5°F (Fig 1).

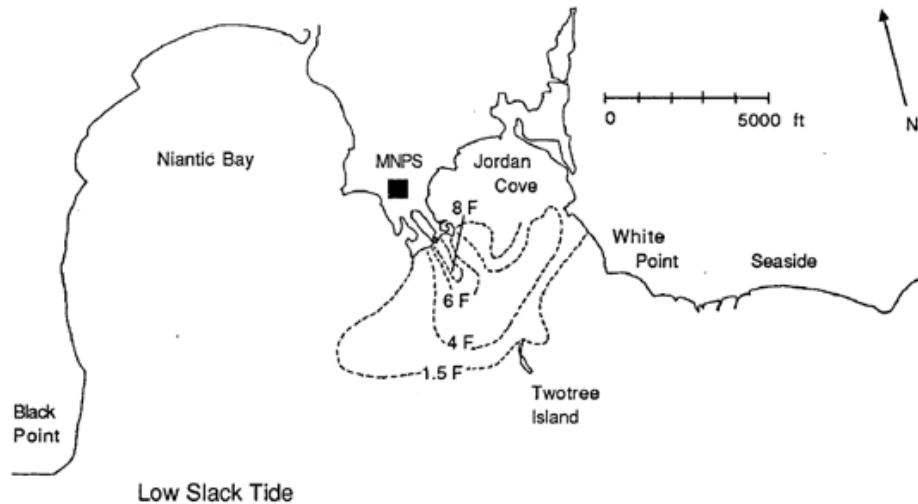


Figure 1. Model of the thermal plume, from Millstone Power Station as well as the layout of the power plant (Adams 2001).

The natural tidal flow in Niantic Bay helps to dissipate the thermal plume. The tides are semi-diurnal and have a mean and maximum range of 0.8 and 1.0m, respectively. The average tidal flow is $3,400\text{m}^3\text{sec}^{-1}$ (NUSCO 1983). The current velocities are 1-18 knots; they are strongest in the channel between Twotree Island and MPS, and are relatively weak in Jordan Cove and in the upper Niantic River. The environmental lab at MPS monitors the environmental impacts of the discharge in the surrounding area in compliance with NPDES (National Pollutant Discharge Elimination Systems) permits. The program covers the following areas: northern portions of the Niantic River, throughout Niantic Bay, Jordan Cove, Giants Neck, and White Point.

The MPS environmental lab has been monitoring the lobster population around Millstone Power Station from 1978 to the present. This lobster study regularly monitors lobster catch in 20 traps at each of the three stations: Jordan Cove, Twotree, and Intake. At each

station, the traps are organized as 4 trawl lines, with five traps each. Benthic otter trawls are also done in Niantic Bay to monitor the benthic communities there. Changes in abundance of adult and juvenile lobsters in the MPS study area have paralleled trends seen in the broader Long Island Sound population. Although the decline in lobster abundance has stabilized, the catch per unit effort has dropped by >74% (CPUE) in the traps and >99% (CPUE) in the otter trawls during the past five years compared to the 1990s (Annual Report 2015). There are multiple stressors that have caused this decline; the rise in ambient seawater temperature, increased predation by the Tautog caught in the lobster traps and epizootic shell disease.

There are many types of shell disease that have been observed in American lobsters, but the most common is Epizootic Shell Disease (ESD). ESD is classified as the breakdown of a lobster's cuticle caused by bacteria colonizing the shell surface (Quinn *et al.* 2013). Quinn *et al.* (2013) found that the bacteria most commonly associated with ESD were *Vibrio pseudoalteromonas* and various *Flavobacteria*. These bacteria cause yellow to orange lesions (Quinn *et al.* 2013) and when these lesions extend through to the gill membrane they can lead to mortality (Malloy 1978). ESD also impacts the cellular health of lobsters as well, lowering the individual's ability to deal with physiological stress. The lobster's main cellular defense response rests with their hemocytes which act through phagocytosis to remove pathogens (Goldenberg & Greenberg 1983). Lobsters have four main types of hemocytes: prohyalocytes, hyalocytes, eosinophilic granulocytes, and chromophobic granulocytes. These cell types vary depending on their nucleus state and cell shape. Prohyalocytes have a condensed nucleus and a spherical cell shape while

hyalocytes have an uncondensed nucleolus and are spindle shaped. The eosinophilic granulocytes have a semi-condensed nucleus with an ovoid shape while the chromophobic granulocyte cells have a spindle shaped nucleolus (Cronick and Stewart 1976). These hemocytes are responsible for the immune response for *Homarus americanus*.

This immune response is highly temperature sensitive. When temperatures exceed 20°C oxygen consumption increases in lobsters and they behaviorally seek cooler water. If they cannot find cooler water the resulting physiological stress can increase disease susceptibility. At temperatures of 22°C - 23°C the phagocytic response of lobster hemocytes is severely compromised (Steenbergen *et al.* 1978). Thus, it is thought that the temperature suppression of the immune system is a driving force behind the increase of ESD noted in southern New England. For example, Glenn and Pugh (2006) found that the prevalence of ESD increased as the mean bottom water temperature increased along the Massachusetts coast. On a smaller scale, my study has investigated the distribution of shell disease and immunocompetence in the lobster population around the thermal plume of MPS and in particular to determine if there was an increase in shell disease prevalence in the near shore site of Jordan Cove.

METHODS

The bulk of this project relies on data provided by Millstone Environmental Lab.

Field Sampling

Lobsters were fished from May through October using twenty vinyl-coated wire traps per station. A total of five traps per four trawls were monitored at three sampling locations: Jordan Cove, 0.5km east of the MPS discharge at a depth of 6 m, Intake, 0.6km west of the discharge with an average depth of 5 meters, and the Twotree station 2km offshore with an average depth of 12 meters (see Fig. 1). From 1978-2011 the pots were fished and rebaited three times a week. From 2012 to present the pots have been fished twice a week from April to October. Data collected on each lobster include: gender, presence of eggs, egg stage of development, carapace length, crusher claw position, missing claws and legs, presence and severity of disease, tag scars, molt stage, and the maximum outside width of the second abdominal segment (for females only). Lobsters were tagged with a serially numbered orange tag and then released where they were caught. At each station, temperature of the surface and bottom water was recorded, as well as the salinity. EDS is indicated by shell pitting, shell erosion, and ulceration (Glenn and Pough 2006). Intensity of EDS on *Homarus americanus* is measured by the proportion of the carapace covered by the bacteria. A score of 0% is given when no shell disease is present, low indicates that 1-10% of the shell is covered by lesions, moderate indicates that 11-50% is covered while severe indicates that 51-100% of the shell is covered (Glenn and Pough 2006). The MPS monitoring program uses a slightly different scheme where NA is equals

to 0%, 1S is equivalent to the low category, and 2S and 3S are equivalent to moderate and severe categories, respectively (MPS Annual Report 2016).

Collection of Hemolymph

I collected hemolymph from a total of 18 lobsters at the three sampling locations on October 9th and 30th 2017, with help of MPS employees. Lobsters were hauled up in the traps, an antibacterial wipe was used to disinfect the joint between the tail and the abdomen, and hemolymph was sampled after the lobster was tagged. Following the methods from Dove *et al.* (2005), I used a 25 gauge needle and 1 ml syringe to collect 200 μ L of hemolymph, which was then dispensed into a vial containing 800 μ L of 10% formalin in seawater. The lobsters were subsequently released. Hemolymph samples were kept on ice until they were processed at the University of Maine in the Rawson Laboratory. Total hemocyte counts were completed using KOVA Glastic Slide 10 with Grids following the protocol of the manufacturer. From each sample three subsamples were counted and the counts from all three summed to obtain hemocyte counts.

Statistical Analysis

A chi-square test of association was used to determine the difference in ESD prevalence per station. Prevalence in this study is defined as individuals showing any sign of disease (1S-3S) divided by the total population. A one-way ANOVA was used to determine any differences in mean bottom water temperature across stations. Another chi-square test of association was used to determine if gender ratios at each station were associated with ESD prevalence. Linear regression analysis was used to determine relationships between bottom water temperature and incidence of disease.

RESULTS

Prevalence of Shell Disease at Millstone Power Station

ESD in the MPS lobster population from 1984-1998 was extremely low, but showed a 20-fold increase from 1998-2001. Initially there was a higher prevalence at Intake compared to the other two sites (Fig. 2). Prevalence of shell disease peaked at all three sites in 2011 at ~0.2% and has since declined to 0.12%. A comparison of the mean prevalence of shell disease at each site over the years 1998 to 2016 indicates there was a significantly higher proportion ($\chi^2_{d.f.=1} = 200.22$; $p < 0.001$) of shell disease among Twotree (TT) lobsters (Fig. 3). Mean prevalence at this site was approximately 20% higher than at Jordan Cove (JC) or Intake (IN).

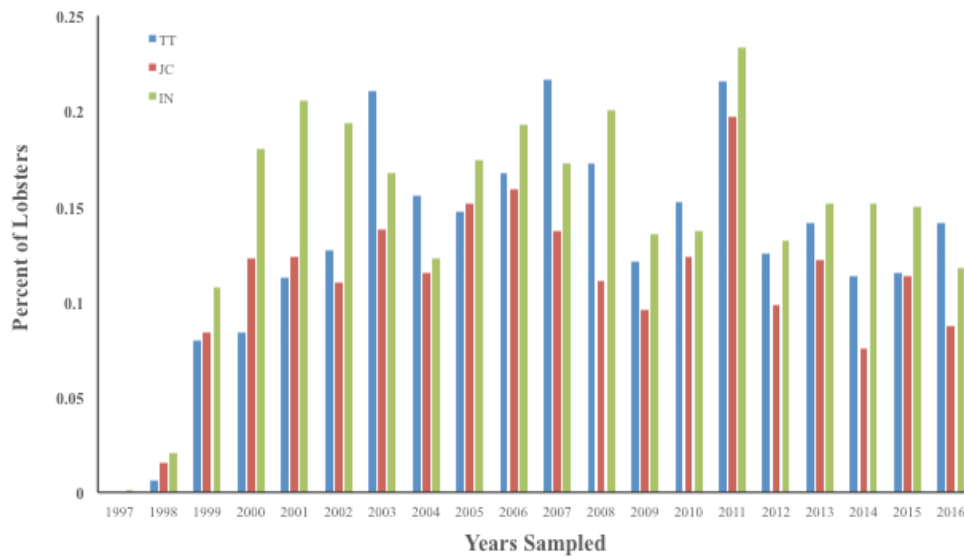


Figure 2. The percentage of lobsters showing signs of shell disease at Twotree (blue bars), Jordan Cove (red bars), and Intake (green bars) over the years 1997 to 2016. Proportions include lobsters showing any sign of shell disease. Ranging from 1S (low)- 3S (severe).

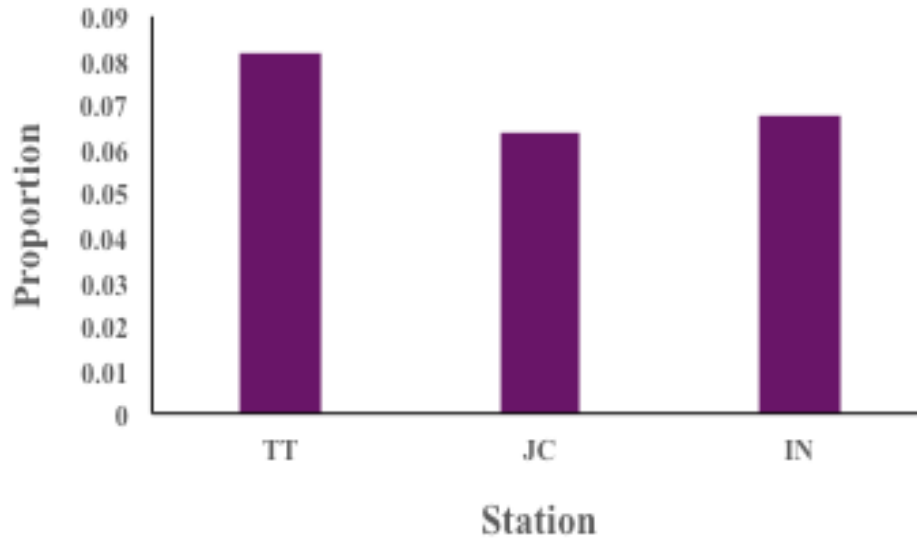


Figure 3. Mean proportion of lobsters with any stage of shell disease at three stations (TT) Twotree, (JC) Jordan Cove, and (IN) Intake near MPS for the years 1984-2016.

Bottom Water Temperatures

Overall bottom water temperature at all three stations near MPS has increased 0.5°C over the past 10 years (Fig. 4). In one year (2009) the average temperature decreased by 1°C, but in other years, such as 2012, temperatures were 0.5°C warmer than in the preceding year. Even though there however was no significant differences in bottom water temperatures among the three stations, Twotree, Intake and Jordan Cove ($F_{2,27}=2.201$, $p=0.13$) due to the strong inter annual variation at each station in bottom water temperatures.

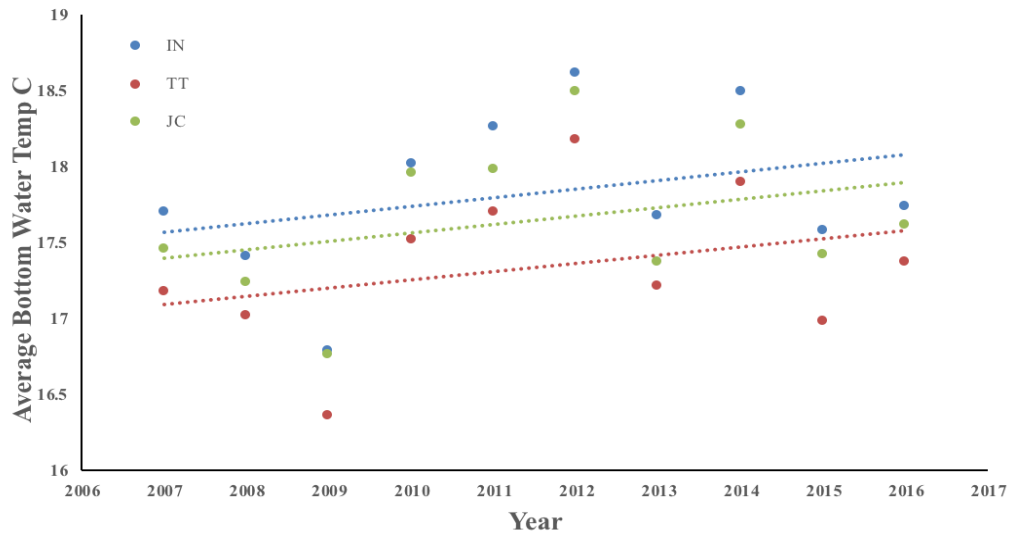


Figure 4. Shows the yearly average bottom water temperature sense 2007 at each station. The linear trend-line shows R^2 values of 0.0997, 0.0975, 0.103 for Intake, Twotree, and Jordan Cove respectively.

It is important to recognize that the yearly average temperature does not reflect the number of days that peak temperatures exceed 20°C , which represents a thermal threshold above which American lobsters experience physiological stress and increased risk of EDS (Glenn and Pough 2006). The number of days where the bottom temperature exceeded 20°C was lowest at Twotree, and highest at Intake ($\chi_{d,f=2} = 9.36$ $p=0.003$). A chi-square analysis indicated these differences in number of days above 20°C between the stations were significant.

Table 1. The number of days at or below 20°C from 2007-2017 at Intake, Jordan Cove, and Twotree sample stations.

Site	Above 20°C	Below 20°C	Total Days	Proportion
IN	226	363	589	38.37
JC	204	385	589	34.63
TT	174	408	582	29.90

Trusty and Metzler (2012) hypothesized that the bacteria associated with ESD grew faster at temperatures at or slightly above 15°C. Twotree had the lowest proportion of days above 15°C, followed by Jordan Cove, while Intake had the highest number of days above or equal to 15°C. However, the difference was not statistically significant ($\chi^2_{d.f=2} = 0.78$ $p=0.677$).

Table 2. The number of days that bottom temperature was equal to and above 15°C from 2007-2017

Site	Above 15°C	Below 15°C	Total Days	Proportion
IN	464	125	589	78.78
JC	457	132	589	77.59
TT	446	136	582	76.63

Association of Bottom Water Temperature with Disease Prevalence

Glenn and Pough (2006) observed a correlation between bottom water temperature and prevalence of shell disease. I used a linear regression to model the annual prevalence of lobsters with shell disease as a function of yearly average bottom water temperature at each station over the past ten years. Although total prevalence varied between sites, (Fig

3) there was no relationship between temperature and prevalence (Fig, 5). The R^2 values ranged from 0.001-0.008. No relationship was found between the bottom water temperature average over the last 10 years and the proportion of shell disease at each station.

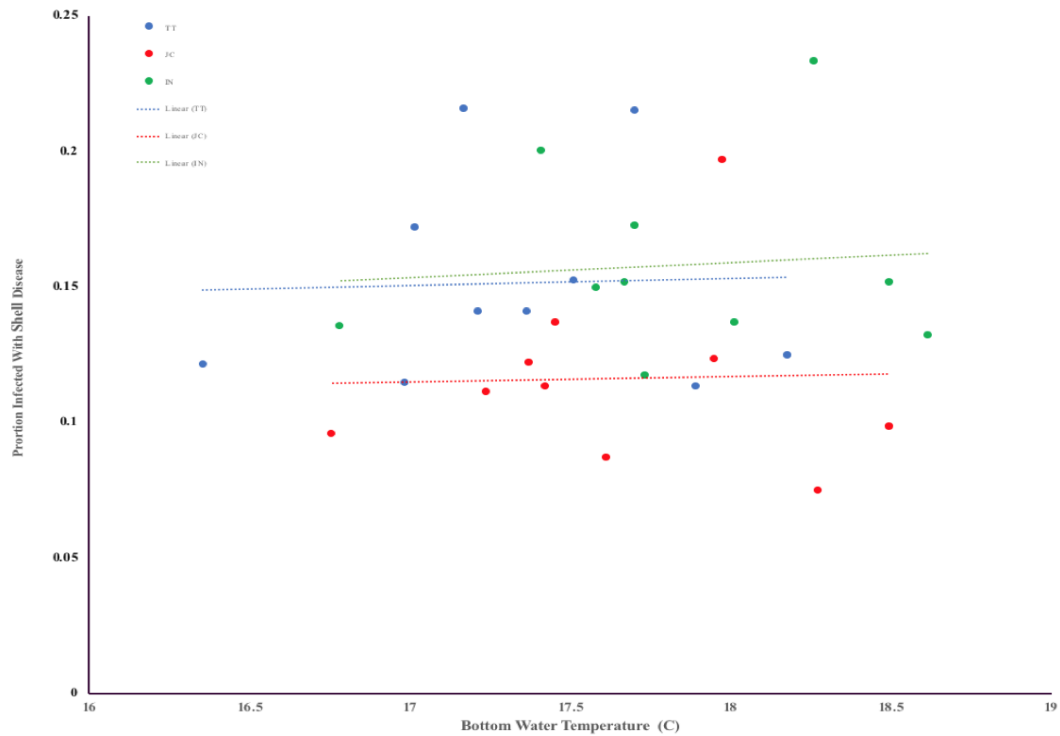


Figure 5. The relationship between average bottom water temperatures at each station over the past 10 years, and the percent of the sample population infected with any degree of shell disease at each station from 1S-3S.

Association Between Gender and Shell Disease

I determined the frequency of shell disease in relation to the gender of the lobsters at each station. There was a significant difference in the ratio of females to males at each station. Overall, Twotree had more females than any other station over time (Figure 6). A chi-square test of association showed a significant difference between number of males and females infected with the disease at each station. The values for females were ($\chi^2_{d.f.=2} = 149.78$; $p < 0.001$) and for males ($\chi^2_{d.f.=2} = 109.43$; $p < 0.001$). The prevalence of ESD was 16% higher in males compared to females at intake ($\chi^2_{d.f.=1} = 41.4$; $p < 1.23 \times 10^{-10}$). 27% more at Jordan Cove ($\chi^2_{d.f.=1} = 41.442$; $p < 1.23 \times 10^{-10}$) and ~4% at Twotree ($\chi^2_{d.f.=1} = 27.8$; $p < 1.3 \times 10^{-7}$).

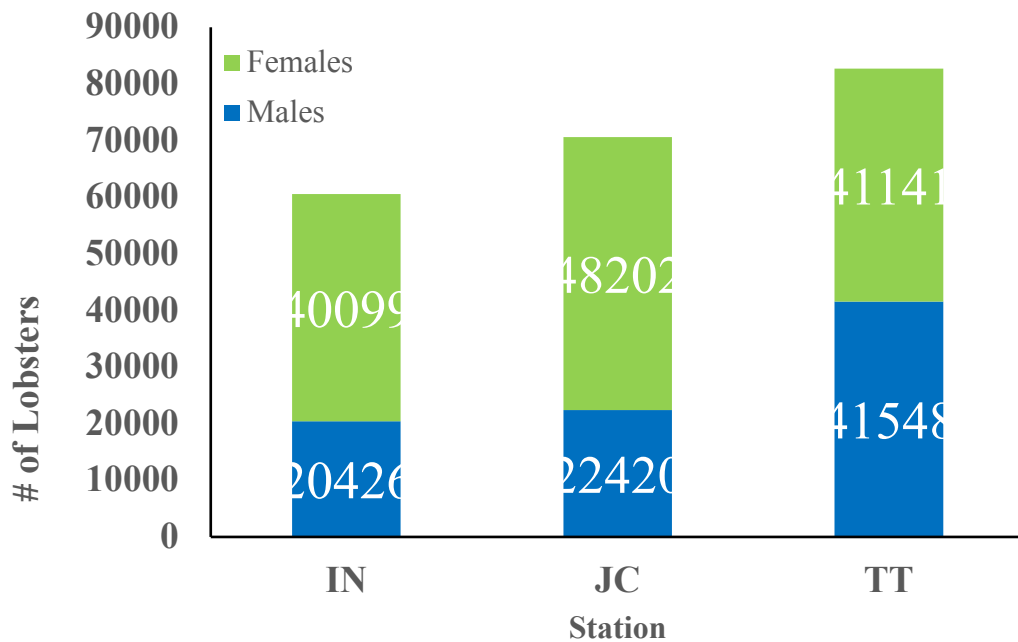


Fig. 6. The total number of lobsters caught from 1984-2017 at IN (intake), JC (Jordan Cove), and TT (Twotree)

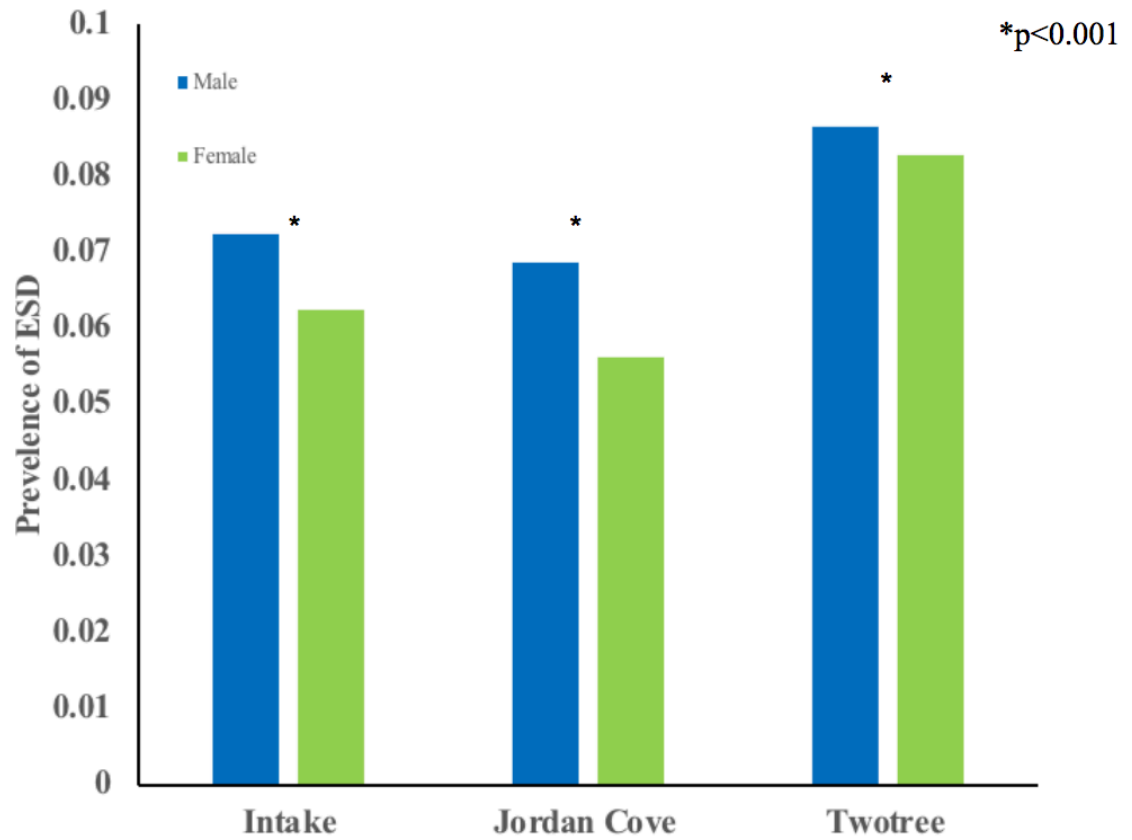


Figure 7. The total percent of male and females, from 1984-2016 that showed any signs of shell disease ranging from 1S-3S. $*p < 0.001$

Immunocompetence

Total hemocyte counts were obtained from 18 lobsters during the summer of 2017. There were fewer hemocytes in disease free lobsters, while the highest observed hemocyte counts were found in the 2S lobsters. Although highest individual hemocyte count was in a 3S lobster, the 3S lobsters had a large range in hemocyte counts. Due to the small sample size, the statistical significance of any differences in hemocytes was not determined.

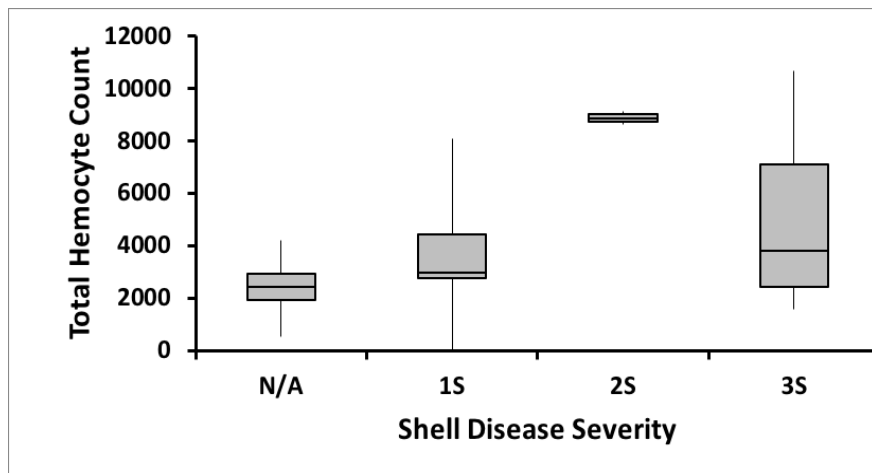


Figure 8. Shows the amount of hemocytes counted in each sample. Shell disease severity was determined in the field, using methods described above.

DISCUSSION

At its peak in the late 1990s, the Connecticut lobster industry was worth \$12 million with fishermen bringing in 3.7 million pounds of lobster annually. In 2014, the industry was worth \$600,000 dollars and brought in 127,000 pounds of lobster (Spiegel 2014). The decline in lobster abundance has negatively impacted the coastal economies of southern New England states and has instilled fear in the northern ones (i.e. Maine).

Understanding what led to the decline in lobster abundance in southern New England can hopefully help Maine's industry prepare for the future. Lobster mortality in southern New England was found to be the result of multiple stressors. These stressors included warmer water temperatures, hypoxia, the release of sulfide and ammonium from the sediment, pesticides, the parasitic amoebae *Neoparamoeba pemaquidensis*, and a rise in ESD (Gomez-Chiarri, and Cobb 2012). Studies by Glenn and Pough (2006) and Dove *et al.* (2005), suggest that there is a strong correlation between ESD and increasing bottom water temperatures. My study looked into the distribution of shell disease around Millstone Power Station (MPS) in relation to a gradient in temperature related to the thermal plume created by MPS cooling water discharge. This study also examined the immunocompetence of a small number of diseased lobsters in the surrounding waters.

A significant positive correlation between shell disease prevalence and daily average water temperature at MPS was reported in previous years (MPS Annual Report 2016). There was also a correlation between the percentage of dead lobsters and the number of days when seawater was above 20.5 °C (MPS Annual Report 2016). Temperature stress

impacts lobsters in many ways. Temperatures greater than 20°C are correlated to increased risk of anoxia and are therefore stressful to lobsters (Wahle *et al* 2009). Tlusty and Metzler (2012) did a laboratory study on populations of juvenile American lobster, rearing them in temperatures of 10°C, 15°C and 20°C. They concluded that lobster cuticle is thinner when grown in warmer temperatures, there is an increased rate of bacterial growth in warmer waters, and the lobsters that were held at 20°C had a shorter molt period (62 days vs 136 days held at 10°C). The greatest shell disease was reported by Tlusty and Metzler at 15°C and mortality was not dependent on disease stage.

Temperature, however, is not the only factor affecting the prevalence of ESD.

In my study, no relationship was found between bottom water temperature and shell disease prevalence when each station was examined individually. Furthermore, the site with the highest prevalence of EDS was the offshore station, Twotree, while the station closest to the thermal plume, Jordan Cove, had the lowest, indicating the thermal plume was not the reason for the distribution of shell disease between the sampling sites. This was further supported by the difference in the proportion of stress when estimated as a proportion of warm days. Intake had the highest number of days above 20°C, while Twotree had the highest prevalence of shell disease. Castro *et al* (2006) investigated the distribution of shell disease in Narragansett Bay and they too found no relationship between shell disease and average water temperature. Temperature is only one factor that contributes to ESD prevalence.

Previous studies have indicated that epizootic shell disease does not impact male and female lobsters equally (Gomez and Cobb 2012 Glenn & Pugh 2006). Females were more likely to have shell disease which was attributed to the longer intermolt times for females, specifically when bearing eggs (Glenn & Pugh 2006). The data from Millstone Power Station is congruent with these results. Twotree had the highest percent of the total population infected with shell disease; Twotree also had the highest number of females infected with shell disease, as well as the highest overall ratio of females. It was also found that shell disease impacts egg bearing females more severely which can lead to a population shift over time favoring males (Glenn & Pugh 2006). It was stated in the MPS 2016 Annual Report that female:male gender ratios have been declining over time, and in 2016 the ratio was one of the lowest at 0.46 (MPS Annual Report 2016). Overall, the distribution in shell disease at each site at Millstone Power Station is a reflection of population composition, not bottom water temperature.

Warmer springtime water temperatures were correlated with an early spring molt event. This, in turn, can lead to a longer intermolt period during the summer which increases the duration ESD bacteria can grow on the shell. The early molt in the spring was correlated with ESD in male adult and juvenile lobsters at MPS (Groner *et al* In prep). Therefore, molting has an impact on disease prevalence that further supports my hypothesis that the distribution of shell disease by station at MPS is related to site-specific variation in gender ratio. Looking further at molt stages by station would help to further confirm this hypothesis. If the lobsters at Twotree take longer to molt, due to the cooler water

temperatures, then those individuals would have a longer time for shell disease to accumulate on their shells.

Another explanation for the distribution of ESD is the mobility of the lobster population at MPS. However, recapture data from 2016 indicated that lobsters were caught at the same station at which they were captured and released in previous years (MPS Annual Report 2016). Since 1978 recaptured lobsters have been caught within 5 km of MPS. American lobsters in Long Island Sound have shown a strong homing behavior (Stewart 1972). Thus, the lobsters around MPS do not show a tendency to undergo long migrations and it can be inferred that the lobsters caught at each station spend a majority of their time there.

Lobsters lack an adaptive immune system and rely on hemocytes in their hemolymph for immune response. Hemocytes use phagocytosis as their primary immune response (Stewart 1976). Immunocompetence is a measure of an individual's ability to fight off disease and can be measured in the number of hemocytes actively undergoing phagocytosis. Dove *et al*, (2005), found that phagocytic activity decreased significantly over a period of prolonged thermal stress at 23°C. They also found that total hemocyte count decreases over time. Therefore, immunocompetence can be impacted by temperature. Another study found that eastern Long Island Sound lobsters had more shell disease and showed signs of decreased immune systems compared to those in western Long Island Sound and Maine (Homerding *et al* 2012). Homerding *et al* (2012) measured phagocytic activity, antimicrobial activity of the plasma and respiratory bursts. The

hemocytes they collected in June 2008 had significantly lower phagocytic activity than those sampled in October or August in the previous years further indicating that immunocompetence is impacted by temperature. I found that the highest number of hemocytes counts were in the individuals categorized with having a disease severity of 2S and a decrease in cell count in lobsters with 3S shell disease, although there was high variance in hemocyte count in this latter group. It is important to note that I was limited to an extremely small sample size so that the 2S category had only two individuals. I planned to run phagocytosis assays; however, due to the sample site being in Connecticut and the lab equipment being in Maine it was not completed. Based on the study by Dove *et al*, (2005), I would have expected to find a decrease in phagocytosis as disease severity increased.

CONCLUSION

In conclusion, the strongest association I observed was between gender and prevalence of ESD prevalence at MPS. No correlation was found between site-specific bottom water temperature, by site, and shell disease prevalence and hemocyte counts were highest in 2S lobsters and lowest in disease-free lobsters. Further investigations should examine molt timing by station and its correlation to shell disease. Understanding the mechanism that led to sharp increase in ESD and mortality in American lobsters in LIS can help fisheries managers prepare for the warming water temperatures in Maine and their implications for the Maine lobster population. An article published in the Portland Press Herald on April 11, 2018 titled, “Lobster shell disease up slightly in Maine” reported that up to 1% of the population was impacted by ESD. Deborah Bouchard of the University of Maine Aquaculture Research Institute was quoted saying that “I don’t know if we can even call it emerging yet;” “it”, however, is on the radar and needs to be studied and understood.

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CHAPTER TWO

INTRODUCTION

During the summer of 2017, Dominion Energy was in the middle of a settlement case between the company and the National Parks Conservation Association (NPCA).

Dominion Energy was closing the Yorktown coal plants in Virginia because they could not meet new standards for toxic gas emissions. The peninsula where the coal plants were located, however, still needed the electricity generated from the power plants to provide emergency power to the grid, as mandated by the state. A solution was that Dominion Energy would provide the electricity by running transmission lines across the James River. The NPCA was worried about the degradation of national park sites, such as Colonial National Historical Park, and the James River. The group argued that there were other options that Dominion Energy was not exploring. The State Corporation Commission sided with Dominion Energy and stated that other options were not feasible, a decision upheld by the Virginia Supreme Court and the Army Corps (Ress 2017).

Currently the transmission lines are under construction. The polarizing question in this lawsuit centered around where is the (transmission) line between environmental degradation and providing the energy that society depends on? This question is also illuminated within the broader public debate surrounding the use of nuclear energy.

We, as citizens of a developed nation, expect to flip a switch and have electricity. This is now becoming the norm in developing countries all over the world. The International

Energy Agency predicts that primary energy demand will increase 45% between now and 2030. That is a total of 3140 gigawatts of energy by 2030 (Kessides 2013). If this gap is bridged using coal, greenhouse gas emissions will rise 28 to 41 billion tons a year (Kessides 2013). In a world where energy demand is increasing, the atmosphere's ability to hold CO₂ emissions is decreasing (IPCC 5th Assessment); does this call for expanded use of nuclear energy?

Nuclear energy is highly controversial. Proponents of nuclear energy point to its low downstream carbon costs, its ability to create jobs, and its ability to provide constant power to the grid (Iseri *et al*, 2018). Concerns with renewable resources such as wind and solar, center on these sources inability to provide constant power and our limited ability to store energy in the form of batteries. Nuclear energy can replace the base-load power that fossil fuels produce now (Hejazi 2017). In comparison to the burning of fossil fuels, nuclear fission creates steam that then powers turbines, but does not emit carbon dioxide; the entire nuclear power chain releases 2-6 grams of carbon dioxide per kilowatt-hour (kWh). Nuclear energy is looked at in the developing world as a way to increase the standard of living in an area and create jobs. For example, it is hypothesized that if Turkey adopted nuclear energy it would create numerous, high paying jobs for the people of Turkey, increase the standard of living, and provide an avenue for technology transfer (Iseri *et al* 2018). Although storage of spent fuel is a concern it has been calculated that the total tonnage of spent fuel globally is only 12 thousand tons, compared to the 25 billion tons of carbon dioxide produced a year (Hejazi 2017), and the cost of managing spent fuel is only 0.5 cents per kWh. These arguments look at the benefits of nuclear

power in terms of the social implications as well as the emission reductions when arguing for further use of nuclear power.

The opponents of nuclear energy point to the high upstream cost of production, the extreme potential for environmental degradation, as well as limited amount of available uranium for fuel production (Iseri *et al* 2018). The cost of building nuclear power plants is extremely high and normally exceeds proposed value (Iseri *et al* 2018). Areas where new powerplants have been proposed are often in earthquake or other natural disaster-prone areas, which is the case for the proposed plant in Turkey. Opponents fear that the standard of living for populations near the plant will be lowered due to radioactive waste and construction of nuclear plants could cause the displacement of people. Opponents also point to the poor grid infrastructure and say that the transmission of electricity needs to be improved to reduce emissions before nuclear power plants come online (Iseri *et al* 2018). Nuclear power plants have a lifespan similar to oil, coal and natural gas (Kessides 2013). In this period of increasing energy demand, is nuclear energy needed? And can it be considered renewable or sustainable? There are varying opinions from economists and environmentalists alike. I was interested in comparing the opinions of the people that work in the nuclear energy industry, specifically the employees at the Millstone Nuclear Power Station owned by Dominion Energy, to definitions of sustainability and responsibility as reported in the literature.

Different factors influence perceptions on environmental protection and nuclear energy. These factors can stem from the current political climate, our place of work, as well as

personal beliefs. The questions I asked, in the form of semi-structured interviews, hoped to highlight the origins of these thoughts and perceptions surrounding nuclear energy. The United States is in the process of pulling out of the Paris Agreement. This was met by states, towns, and companies pledging to continue to uphold the Paris Agreement, even if the United States as a whole pulls out. The first question in the interview was meant to see if the employees at Dominion Energy cared about the company's carbon emissions and to see if, as a company, they are actively reducing emissions to uphold the Paris Agreement. The second question was meant to determine if, in their work day, they were conscious of the impact of their work has on the environment, including the total cost of carbon throughout the life cycle of nuclear energy. The impetus for this question was rooted in the idea that employees are alienated from their labors true purpose. The third question was to understand where the employees that work in the energy sector stood on what it means to provide power that people expect and need while simultaneously protecting the environment. The next question sought to understand their personal definition of sustainability and where MPS employees thought nuclear power fell into their own definition. The final question focused on if these employees thought about the injustice that climate change has on developing countries and to see if they think their company should be held accountable for the environmental repercussions, such as flooding, that comes with climate change. This question stemmed from the Divestment Movement, which uses market to pressure on fossil fuel companies to be held accountable for their actions (and lack of actions) regarding environmental degradation and climate change. The movement was essentially asking that fossil fuel companies pay developing nations for their loss of homes using public stigmatization pressure. I was

investigating if the employees of a power company felt any guilt and thought that they should be compensating developing nations. These informal interviews set out to understand the mindset of nuclear industry employees regarding sustainability and energy production.

METHODS

Over the course of summer 2017, I conducted five individual, semi-structured interviews with employees at Millstone Nuclear Power Station (MPS) with IRB approval. The interviews were formatted as a semi-structured conversation that lasted from 30 to 60 minutes. Some were conducted in person and some were conducted over the phone. To select interviewees, names were provided by the supervisor of personnel in each of the following departments: chemistry, operations, security, health physics, environment, as well as human resources, maintenance, and licensing. Each of the individuals that were interviewed were sent a recruitment email found in Appendix C. Volunteers for interviews were approached individually; selection of the interviewees was a non-random process, and they were asked to participate in a sustainability interview to complete a senior thesis project. Each individual was assigned a number and referred to as that number throughout the coding and note-taking process. The goal was to get a cross section of the workers in the power plant; however, based on timing and who responded I did not have the opportunity to interview a person from each department.

While each interview varied in the material covered, each respondent was asked a version of the following questions:

1. Is Dominion Energy doing enough to reduce its carbon emissions?
2. How often during your work day do you think about the repercussions of nuclear energy?
3. Where do you stand on keeping the lights on versus environmental degradation?

4. Please define “sustainability” from your perspective.
5. As a global citizen, how do you feel you fit in regarding the injustice that climate change has inflicted on people of lower incomes in this country and other countries around the world?

Interview transcripts were typed into Microsoft Word, and holistically analyzed looking for repeated phrases, common themes, and outliers. Responses were then binned into the following categories: emission reduction, environmental repercussions of nuclear energy, commitment to producing electricity, definitions of sustainability, and climate justice. Once responses were binned, they were then compared to responses found in the literature to similar questions.

RESULTS

Across the board, the results from the interviews indicated that the employees viewed nuclear energy as base-load transitional energy source. They thought that it is not 100% renewable and should be in its own category, because it does reduce greenhouse gas emissions. Each interviewee spoke highly of Dominion Energy's reduction of fossil fuel emissions and movement towards a more diversified 'fleet'. They viewed providing energy as a primary concern of the company. Sustainability was looked at from more of a business sense than an environmental one, and none of the interviewees appeared aware of the concept of climate justice. The individual responses to each question are grouped below.

When asked: **Is Dominion Energy doing enough to reduce its carbon emissions?**

The answer from each of the five interviewees was a unanimous yes. The reasons given ranged from diversity in the market, to being a good corporate citizen, to risk and opportunity management. One interviewee stated Dominion Energy will lower emissions even if the U.S. has pulled out of the Paris Agreement, [Dominion is a] good corporate citizen"; another indicated that the "business model is there, but not strong". Each interviewee was proud of the emissions cuts.

When asked: **How often during your work day do you think about the environmental repercussions of nuclear energy?** The answers spanned from a little, in reference to public safety regarding meltdowns to more frequently with one interviewee saying "every minute [of] everyday [all] I do [at] millstone is the impact of nuclear power." Another

interviewee mentioned concern over the use of water to cool the plant and the entrainment of marine organisms.

When asked: **Where do you stand on keeping the lights on verse environmental degradation?** Most did not fully answer this question. “Electricity is so integrated that we take it for granted... [it] becomes a cost benefit thing [a] money driven process” and another stated nuclear power should be considered sustainable due to low emissions. Another stated that there is a lack of education among the public and that some people are willing to pay more for “clean energy.” Most indicated that we, as a country and consumers, need electricity so it was a priority not just that the environment was not.

When asked: **Define sustainability.** The answers ranged from “a proactive business plan” to “continue the practice into the future without depleting the resources” to “Nuclear energy is a category of its own, and has ways to become more sustainable.” One mentioned “the capacity to endure” and, “[To] sustain our business interests for our stakeholders and career turning opportunities.” Another stated, “Long term plan keep the programs that you have [to] continued to be successful and how can you improve them [as you] need to keep things up”. This interviewee then went on to list the concerns of those in charge of hiring employees. These concerns include knowledge transfer, and the reputation of Dominion energy. Other thoughts on sustainability were to sustain and improve a business plan. The interviewee then said that nuclear energy is not renewable and has ways to become more sustainable.

When asked: **As a global citizen how do you feel you fit in regarding the injustice that climate change has inflicted on people of lower income in this country and other countries around the world?** The answers ranged from strong responses, “I don’t think climate change is man-made, has had a minuscule impact, look at the 3rd world China and India to me that’s unfair because they have so many people they need to do more, our companies are doing more than they need to”. Another interviewee talked about the fact that MPS is in a nice area with higher average income where other energy plants, such as coal plants, are normally found in places with lower than average income. One mentioned that Dominion paid to clean the coal ash off of boats, while another mentioned that they were unsure if Dominion is providing any compensation (to negatively impacted nations).

DISCUSSION

Diversity in the Market

The employees at Dominion Energy thought that, as a company, they were doing enough to reduce their carbon emissions. This opinion may stem from the employees viewing their company as ‘diversified’ in the market. In a comparative study of energy supply diversification in Nordic Countries, Aslani *et al* (2012) looked at the benefits of energy diversification. The percent of renewables in Nordic countries individually are as follows: Finland has 31.56% renewables, Sweden at 58.52%, Norway with 96.63%, Denmark at 27.4, and Iceland with 100% renewables (Aslani *et al* 2012). The comparative analysis used the DESS (Diversification of energy supply sources) values to determine diversity levels in each country. The equation is as follows,

$$DESS = - \left(\frac{\sum_{i=1}^n a_i * \ln(a_i)}{\ln(n)} \right).$$

where n= number of energy sources and A_i = share of primary energy sources in the total energy supply. It was found that countries with larger DESS values showed reduced vulnerability of supply disruptions and reduced risk to their energy supply. A large DESS value was also correlated with lower price fluctuations. The study concluded that in order to promote diversification, investment supports are needed as well as tax rebates and bonuses, taxes on fossil fuels for heat production, and increased storage capacity of renewable energy sources (Aslani *et al* 2012). Each form of energy has its own risk associated with it (Miser 2017). With multiple sources of energy, a company can bridge

the economic downside of each energy source and create a whole that is greater than the sum of its parts (Miser 2017). Employees at Dominion energy felt that reduction in carbon emission was important, but only within the concept of diversification.

Definitions of Sustainability

A trend seen in the definitions of sustainability across the interviews were that each employee focused on the economic over the ecological aspects of sustainability. The people that worked in the plant were more concerned with the sustainability of the company, rather than the environment. In the literature there are numerous definitions of sustainability. Two are light green and dark green (Pearce 2012). Light green refers to the near term financial sustainability, while dark green is long term multi-faceted descriptions of sustainability (Pearce 2012). The answers given by the employees at Dominion Energy were congruent with the light green definition of sustainability. The interviewees were concerned with future generations of employees. Not one mentioned the limited supply of uranium, but inferred it by saying nuclear energy is a transition fuel source.

The term sustainability has become an all-encompassing business buzz-word for anything good (Morelli 2011). There has been an ongoing debate regarding definitions of sustainability and where nuclear energy fits into the argument. In 1988 the World Watch Institute defined sustainability as “satisfied in its needs without diminishing the prospects of future generations” (Foy 1990). There are many ways in which people interpret how to achieve this. One way in which ecologists view sustainability is using the safe

minimum levels of environmental assets as constraints on efficiency. The safe minimum standard term was coined by Ciriacy-Wantrup in 1968 (Foy 1990). Morelli (2011) thinks that economic sustainability should include an analysis to minimize the social cost of meeting standards for protecting the environment as an asset, but not determining what those standards should be. An example of this would be ecologists think that economists should take into account the price difference between free-range eggs and regular eggs (Morelli 2011).

In contrast, economists are more concerned that required provisions are made for future generations with reproducible capital. This model of sustainability requires that a monetary measurement be placed on everything in the environment and also assumes that man-made capital can substitute for natural capital (Foy 1990). Economists also think that current economic activity should not disproportionately burden future generations (Morelli 2011).

Both of the forgoing definitions are concerned with future generations. However, the economic view does not fully encompass the human dependence on natural resources and ecosystem services, while the environmental definition does not wholly encompass sustainable business practices. Another definition comes closer merging the gap.

“Environmental sustainability could be defined as a condition of balance, resilience and inter-connectedness that allows human society to satisfy its needs while neither exceeding the capacity of its supporting ecosystem to continue to regenerate the service necessary to meet those needs nor by diminishing biological diversity” (Morelli 2011).

This definition considers the continuation of the business practice, but with attention on the ecosystem services on which it depends.

How Nuclear Power Fits In

In 1987 The World Commission on Environment and Development published *Our Common Future* also known as the *Brundtland Report*. The commission noted in the section deemed “Nuclear Energy: Unsolved Problems” the threat of the proliferation of nuclear weapons. If countries develop technology for nuclear energy they can also develop technologies for nuclear bombs. Other unresolved issues with nuclear power include the cost of building nuclear reactors, the cost of fuel (uranium mining), maintenance cost, cost of endurance, human health risk, and risk of catastrophic meltdowns. These issues have remained leading deterrents in nuclear energy becoming a more common method of energy production. The report recommended that countries remain non-nuclear and develop other sources of energy, although it recognizes nuclear energy as a transition fuel. A transition fuel is a fuel source used in the near term to reduce our carbon emissions, while we further develop truly renewable fuel sources. The report also noted that in using nuclear technology, safety is a huge priority.

Currently, worldwide there is considerable discussion over carbon emissions. However, we have a carbon-based economy where in developed nations we expect and depend on a continuous supply of electricity. The world population is growing as are average incomes and standards of living (Kessides 2013). According to the International Energy Agency, the primary energy demand will increase 45% from present to 2030; this

increase will be led by China and India (Kessides 2013). This translates as growth from 4,343 gigawatts in 2006 to 7,484 gigawatts in 2030. If this increase in energy demand is met by an increase use of coal it will lead to 41 billion tons of CO₂ released per year (Kessides 2013). Nuclear energy's direct production of electricity (not including the upstream cost of carbon that is used to build the plant, and mine uranium) is carbon free. Nuclear energy's upstream cost of carbon is lower than solar and wind (Kessides 2013). Nuclear energy can also provide base-load power that does not fluctuate with changes in weather. With these thoughts in mind, there are ways in which future nuclear energy can become more "sustainable": a drastic reduction of greenhouse gas emissions in the building of the reactors, the mining of uranium, the elimination of radioactive waste, and minimizing environmental impact during mining processes. It is also imperative that nuclear companies regain the public trust (Pearce 2012).

Nuclear power does have a high construction cost; construction of reactors accounts for about two thirds of total generating cost and the reactors take a long time to build. Nuclear power also has the potential for catastrophic failures often with the uncontrolled release of radioactive materials. Chernobyl, Fukushima, and Three Mile Island are three events that come to mind. The day-to-day operation of the plant is also dangerous. As of 1998, the nuclear power industry reported 8 deaths per terawatt year. Even so, this is low when compared to the number of deaths in the larger energy industry; hydropower had a total of 883 deaths per terawatt year of production while coal had 342, and natural gas had 85 (Kessides 2013). Thus, the operation of nuclear power plants is safer than hydroelectric plants in terms of worker safety. To meet the growing energy demands of

the future, nuclear energy may be necessary to reduce overall carbon emissions. All interviewees stated that nuclear energy is needed as a transition fuel source.

Climate Justice

There are many principles in which climate change negotiations between nations can be based upon. Many stem from the concept of distributive justice, which takes into account the normative standpoint on climate change (Santos 2017). The normative standpoint's argument is based off of the idea that historically the greatest greenhouse gas emitters are responsible for the current climatic condition of our planet and therefore should pay for it (Santos 2017). This argument is backed by historical greenhouse gas emission data and the theory of the polluter pays principle. The polluter pays principle was adopted by the Organization for Economic Co-Operation and Development in 1974 (Santos 2017). In my interviews, the question regarding the inequalities between top emitters and who is suffering the most due to climate change was born out of the polluter pays principle.

Another principle negotiations can be based off of is the beneficiary pays principle. This principle contends that countries that benefited from climate changing activities should bear the cost of mitigation and adaptation. Its roots are found in corrective justice, where correcting any injustices is achieved by compensation from the beneficiary (Santos 2017). Another approach is the ability to pay approach, which believes that states should bear climatic responsibilities in proportion to their relative abilities to bear the burdens; that is those who have more resources should make a greater effort. This belief is rooted in and acknowledges that in some cases the states, leaders or companies responsible for

damage no longer exist. This principle is rooted in the moral reasonability to address climate change and is not related to the history of carbon emissions.

Dominion energy has diverse energy production facilities including those based on nuclear power, wind, solar, natural gas, and coal. When asked about compensation that the company gives to those affected by the adverse effects of energy production, one interviewee mentioned Dominion Energy cleaning up the coal ash that aggregated on people's boats downwind of a coal-fired power plant. This response follows the polluter pays principle; where Dominion energy was responsible for the coal ash and paid to clean it up. Regarding compensating other countries that are impacted the most from climate change, one interviewee strongly believed that Dominion should not have to compensate other countries, because MPS is not an emitter and that it is China and India that should be held accountable. This interviewee also stated that they did not believe in anthropogenic climate change and therefore was focused mostly on the reduction of other air pollutants such as sulfur dioxides and nitrous oxides. Their arguments highlight some aspects of the counter to the normative standpoint regarding climate change. The counters to the normative stand point according to Singer (2002) state that the unawareness of past generations for the prejudicial consequences of their greenhouse gas emissions should make it so the equal sacrifice principal is employed. The equal sacrifice principle would also work if it is believed that climate change is not man-made and is a natural phenomenon that each country has to mitigate regardless of human emissions. Some arguments against the polluter pays principle are that countries in the past that were polluting were unaware at that time that they were adversely impacting the environment.

Indeed, it was suggested by Miller (2009) that before 1985-1990 countries could not be held accountable for anthropogenic CO₂ emissions (Santos 2017). This calls for polluters to pay for the emissions. Aspects of these principles are all found within the Paris Agreement, which the employees of MSP stated they would uphold despite the United States pulling out of the agreement.

The Paris Agreement is a non-binding agreement with regard to emission reductions. There are no specific obligations for reduction by developed countries and no special treatment for developing countries. Paragraph 4 of the Paris Agreement, however, states that the least developed countries and the ones that are vulnerable to the adverse effects of climate change will be the top priority for the provision of funds. The agreement does not have a basis for any liability or compensation; this is seen as good for the developed world because no legal actions can be taken based upon this agreement.

When the employees of MPS were asked about the actions that were taken to reduce emissions, one mentioned development of solar power facilities in California, and then followed up and said nuclear provides constant gigawatts to the grid and repeated that Dominion has to be diverse. The employees also talked about Dominion being a good corporate citizen, which is directly related to stakeholder involvement.

Stakeholder Accountability

A common thread in the interviews was stakeholder involvement. Three out of the five interviewees mentioned stakeholder involvement regarding environmental action by the

company. One said “Stakeholders want environmental considerations, how is the company being sustainable, how do you have a sustainable environment? [Its] Not mutually exclusive.” In the most recent Citizenship Report, Dominion Energy explained their growing investments in clean energy. This includes infrastructure growth projects, cleaner-burning natural gas, and 979 million dollars invested in solar technology in 2016. The report also states the company achieved a 43% decrease in carbon emission, and a 96% reduction in sulfur dioxide emissions while nitrogen oxides emissions have dropped 81% from 2000-2015. Incorporating renewables, and getting energy from uranium, waste wood, water, wind, fuel cells, in addition to sun fossil fuels, decreases the risk of spikes in the cost of one single source of energy. This keeps electricity rates low for the users. The report then goes on to state that it is the right thing to do to limit the company’s impacts on the environment. Dominion had a 17.4% return to shareholders, compared to Dow Jones Industrials average of 11.3% in the year of 2016. The company prides itself on its stakeholders. It is this argument that counters the divestment movement. If a shareholder divests, they no longer have a voice regarding company policies.

Danske Bank has identified climate change as a risk to investment and because of this they do not propose divestment from fossil fuels. As climate change is now a risk to investment, shareholders should remain invested in order to propose and enforce methods of carbon emission reduction. Danske Bank thinks it’s best to prioritize best in class companies, and use ESG investing criteria (Batruch 2017). ESG stands for environmental, social and governance and is used by companies to facilitate socially responsible investing. The Institution Investors Group on Climate Change states that a

dramatic shift from oil and gas is neither feasible nor desirable; instead one should consider the next decades as a period of energy transition from non-renewables, to renewables (Bartruch 2017). The ESG investing models depend on stakeholder involvement; this then pushes companies to consider environmental impacts in order to retain shareholders. As the company seeks to be competitive in the market, it is also seeking to lower emissions. One interviewee stated when asked, “should Dominion Energy be considered ESG”, their reply was “energy supply is more complicated”. However, in 2017 the CEO of Dominion Energy claimed at the annual stakeholders meeting that Dominion Energy has reduced its mercury, nitrogen and sulfur emissions by 96%, 81%, and 95% respectively. As a corporation, they have reduced their CO₂ emissions by 43% while the industry as a whole reduced their CO₂ emissions by only 23% (Farrell 2017). In their Citizenship Report their position on climate change was as follows:

“We believe that a national climate change policy should be developed legislatively together with a sound national energy policy that provides fuel diversity a reliable energy supply and affordable electric serves, as well as regulatory certainty and compliance flexibility for industry. This policy should promote the development and deployment of technology based solutions including renewable energy, advanced nuclear, natural gas and clean coal technologies” (Dominion Energy Corporate Citizenship Report, 2015)

Dominion Energy has been diversifying their energy production. They have invested more than \$1.2 billion into solar energy (Ferrell 2017). They have also created an

integrated resource plan that combines nuclear, solar, and natural gas to continue to reduce carbon emissions (Ferrell 2017). While diversifying their company by adding renewables, they are still after one goal: to provide reliable power to their customers. Nuclear power is a way to reduce greenhouse gas emission while still providing base-load power to the grid. Dominion Energy's actions to reduce emissions are congruent with stakeholder involvement and diversifying their energy production fleet.

CONCLUSION

From the five interviews with employees at Dominion Energy, it was striking to me that when thinking about sustainability the employees referred to the sustainability of the company and few referenced environmental sustainability. They understood that renewable resources provide diversification in fuel sources that was good for the consumer and the environment, but they focused on stakeholder engagement to reduce emissions. Nuclear energy was considered a transitional fuel source, due to its ability to provide base load power to the grid, and they believed there was a strong disconnect between the consumers of the electricity and how electricity is made. They each held a strong belief that they were there to provide power to the people. One stated that they are a power company and as a population when the power goes out “we go insane”. Their main goal is to provide affordable and reliable energy in a way that sustains their *business*.

These opinions are drawn from interviews with only a small subset of the company. However, there was repetition among the answers given indicating a common thread in their beliefs. This highlights an important aspect of developing regulations and policies as we move forward in the future of energy production. When policy is being written, it needs to take into account the background of the people it is impacting. Each person that was interviewed had a very narrow view when speaking about climate change and sustainability. None of the interviewees thought about climate change impacting poorer countries with more severity and most did not think that definitions of sustainability

should include the environment. These views contrast those of environmentalists and can point to a polarization of views in our country. Environmentalists need to realize that a realistic use of the environment is necessary for human life. The economists, however, need to realize that for human life to exist the environment has to thrive, as well. Both the environmentalists and economists pointed towards the prosperity of future generations. Combining these two mentalities to find a balance between what it means to be sustainable will allow for the *future generations* to thrive and prosper, the common thread that links environmentalists and economists, alike.

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APPENDICES

APPENDIX A: INTERVIEW QUESTIONS

A. Is Dominion Energy doing enough to reduce its carbon emissions?

- Specifically in regards to expanding its solar and wind energy facilities?
- Should the company look into reducing its carbon emissions even after the US pulled out of the Paris agreement?
- Is the company's push towards renewables coming from an altruistic place, of environmental preservation or is it simply staying competitive in changing markets?

B. How often during your work day do you think about the environmental repercussion of nuclear energy?

- mining process to get Uranium
- the spent fuel and where to store it
- the use of water from niantic bay to cool the reactors
- how much do you know about the environmental monitoring that goes on onsite?
- the amount of carbon that is needed to build the plant, as well as mine uranium

C. Where is your stance, on keeping the lights on vs. environmental degradation?

- Specifically in regards to the skiffs creek power line controversy, where the York coal fired power plant is meant to be decommissioned, but a power line had to go over skiffs creek and resulted in public outcry and a large settlement. Dominion Energy however was just trying to make sure the people had enough power to turn on their lights.
- Any other examples of this conundrum

D. Define sustainability

- using this definition is nuclear energy sustainable?
- what is your response to only 85 years of uranium supply for nuclear power plants?
- Do you think that nuclear energy is more reliable, and therefore a better alternative to coal than solar and wind?
- Do you think that nuclear can be called carbon free? Due to the upstream cost of carbon?

E. As a global citizen how do you feel you fit in regarding the injustice that climate change has inflicted on people of lower income in this country and in other countries around the world?

- loss of freshwater in island nations due to sea level rise
- crop failure
- homes loss
- Storm intensification

APPENDIX B: RECRUITMENT TEMPLATE

Dear _____.

My name is Emily Craig, and I am a summer intern in the environmental lab. I am currently a student at the University of Maine, and for a senior honors thesis, I am conducting a research study. I have received your contact information from my supervisor Don Landers. The purpose of this study is to discover how employees at the Millstone Nuclear Power Station define sustainability, and use that definition to describe the impact of nuclear energy on the environment. I am inviting employees that are 18 years or older to participate in this study. Participants are asked to take part in a 20 minute to an hour long interview, regarding nuclear energy and the environment. I am reaching out to you in hopes to arrange an in-person or over the phone interview, to discuss the highly debated topic of nuclear energy. Your participation would remain entirely confidential and your name would not be linked with anything you say during the interview, nor would your name be published or made public. Your involvement would be greatly appreciated. If you would like to take part in this study or have any questions, you can contact me at emily.a.craig@maine.edu, or 860-287-1295.

Thank you again for your time,

Emily Craig

APPENDIX C: IRB APPROVAL LETTER

APPLICATION FOR APPROVAL OF RESEARCH WITH HUMAN SUBJECTS

Protection of Human Subjects Review Board, 418 Corbett Hall, 581-1498

PRINCIPAL INVESTIGATOR: [Emily Criag](#)
EMAIL: Emily.craig@Maine.edu TELEPHONE: 860-287-1295
CO-INVESTIGATOR(S): NONE
FACULTY SPONSOR (Required if PI is a student): [Dr. Aaron Strong, School of Marine Sciences](#)
TITLE OF PROJECT: What do they think about sustainability? A look inside the Millstone Nuclear Power Plant.
START DATE: [August 15, 2017](#) PI DEPARTMENT: [School of Marine Sciences](#)
MAILING ADDRESS: 354 Aubert Hall Orono Maine 04469
FUNDING AGENCY (if any): NONE
STATUS OF PI: Undergraduate

1. If PI is a student, is this research to be performed:

<input checked="" type="checkbox"/>	for an honors thesis/senior thesis/capstone?	<input type="checkbox"/>	for a master's thesis?
<input type="checkbox"/>	for a doctoral dissertation?	<input type="checkbox"/>	for a course project?
<input type="checkbox"/>	other (specify)		
2. Does this application modify a previously approved project? **No**. If yes, please give assigned number (if known) of previously approved project:
3. Is an expedited review requested? **Yes**

Submitting the application indicates the principal investigator's agreement to abide by the responsibilities outlined in [Section I.E. of the Policies and Procedures for the Protection of Human Subjects](#).

Faculty Sponsors are responsible for oversight of research conducted by their students. The Faculty Sponsor ensures that he/she has read the application and that the conduct of such research will be in accordance with the University of Maine's Policies and Procedures for the Protection of Human Subjects of Research.

FOR IRB USE ONLY Application # 2017-07-16 Date received 7/28/2017 Review (F/E): E
Expedited Category:

ACTION TAKEN:

- Judged Exempt; category 2 Modifications required? y Accepted (date) 8/14/2017
- Approved as submitted. Date of next review: by Degree of Risk:
- Approved pending modifications. Date of next review: by Degree of Risk:
Modifications accepted (date):
- Not approved (see attached statement)
- Judged not research with human subjects

FINAL APPROVAL TO BEGIN 8/14/2017

AUTHOR'S BIOGRAPHY

Everyone says to pursue something that interests you; well that's hard when everything under the sun interests you. Well, actually not everything. It was easy for me to say I did not want to be a mechanical engineer. Other than that, trying to pick an Honors Thesis project proved to be quite difficult. This is why I had two chapters, one filled with ecology and biology and the other with policy and concepts of justice. Justice interests me for many reasons and I was glad I could take the time and do some in-depth research about climate change justice. I also wanted to see what work I enjoyed better, the solitude of hemocyte counting or the chatty interviews? The funny thing is, it depended on my mood. I guess that's why according to Myers-Briggs I am only 56% extraverted, which would qualify me as an ambivert. So after all of this work I am still just as confused as ever about whether I want to pursue marine policy or biology. That's also probably why I am not attending graduate school right away. I think this is just who I am as a person and I hopefully will have a very diverse future. Thank you for taking the time to read my thesis and I hope you learned something about shell disease and concepts of sustainability.