### Thesis Prospectus 2022-23

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**Student Final Submission (date): 12/2/2022**

**Faculty Reader Approval (date):**

**MES Director Approval (date):**

1. **Working title of your thesis[[1]](#endnote-2).**

Implications of Pacific Northwest Climate Patterns on Harmful Algal Blooms and the Subsequent Marine Biotoxins

1. **In 250 words or less, summarize the key background information needed to understand your research problem and question.**

Phytoplankton like *Alexandrium catenella* produce marine biotoxins naturally which can then bioaccumulate in shellfish via filter feeding (Trainer et al. 2003). This results in toxic shellfish that can cause harm to other animals and humans upon consumption. Paralytic shellfish poisoning is an example, most known due to its prevalence and potentially lethal symptoms. It is caused from a neurotoxin produced by *A. catenella* called saxitoxin. Symptoms can include tingling of the fingers and lips, difficulty breathing, and loss of respiratory muscle control leading to death (Van Dolah 2000). Understanding the environmental drivers and climate patterns impacting harmful algal blooms like *A. catenella* can provide insight on a more effective way to monitor and regulate toxic shellfish.

Many factors influence the relative success of harmful algal blooms such as nutrient availability, sunlight, temperature, etc. Climate patterns influence these environmental factors and produce variabilities as well. The Pacific Decadal Oscillation is a climate pattern most known as the source of consistent and cyclical sea surface temperature anomalies in the Pacific Northwest (Schneider and Cornuelle 2005). These weather anomalies could be influencing phytoplankton dynamics (i.e., HAB blooms) and the subsequent marine biotoxins in shellfish (Moore et al. 2010; Newman, Compo, and Alexander 2003; Newman et al. 2016). I plan to compare yearly PDO indices to shellfish saxitoxin (paralytic shellfish poisoning) concentrations to see if there is a relationship.

1. **State your research question(s).**

To what extent do warm and cold phases of the Pacific Decadal Oscillation (PDO) and El Nino southern Oscillation (ENSO) correlate with harmful algal blooms and marine biotoxins (i.e., paralytic shellfish poisoning causing saxitoxin) in the Pacific Ocean along the Washington coast?

1. **Situate your research problem within the relevant literature. What is the theoretical and/or practical framework of your research problem?**

*Alexandrium catenella* is known to proliferate in water temperatures above 13°C (Moore et al. 2010). Blooms of *A. catenella* are directly correlated with the release of saxitoxin and shellfish toxicity with some variability depending on environmental and physical factors (CO­2, temperature, and nutrient levels) (Tatters et al. 2013). It should be known that saxitoxin and paralytic shellfish poisoning concentration as terms are used interchangeably (saxitoxin = shellfish toxicity). Essentially, *A. catenella* is always producing saxitoxin, but the rate can vary slightly. Since warmer sea surface temperatures (above 13°C) are correlated with higher *A. catenella* cell counts and subsequent saxitoxin concentrations in shellfish, we might infer the Pacific Decadal Oscillation (PDO) and the El Nino Southern Oscillation (ENSO) have an impact on paralytic shellfish poisoning.

Moore et al. 2010 found a significant relationship between sea surface temperatures (SST) above 13°C and shellfish toxicity; and PDO and # of days SST above 13°C, but not a significant relationship between shellfish toxicity and PDO or ENSO. There was a positive relationship between PDO and shellfish toxicity, but it was not significant (p= 0.12). The consensus is that there does seem to be a correlation between PDO and shellfish toxicity (PSP concentration), but the myriad of interacting variables makes it difficult to imply causality. My theory is if a positive PDO index is significantly correlated with # of days SST is above 13°C, and this threshold (13°C) is significantly correlated with shellfish toxicity then we could reasonably infer a positive PDO index will likely increase shellfish toxicity as well. I plan to add to this knowledge by running same tests on a more recent timeline to see if the data follows this trend.

1. **Explain the significance of this research problem. Why is this research important? What are the potential contributions of your work? How might your work advance scholarship?**

*Alexandrium catenella* release saxitoxin which is a neurotoxin that can lead to death if not treated immediately. Understanding the PDO and its warm and cold phases could help us predict HABs like Alexandrium catenella which would allow us to better monitor the marine biotoxin (i.e., saxitoxin). This ensures a safe shellfish industry. There are limited studies on this specific research question so I plan to contribute to this limited field of study to provide more insight.

The significance of extending this field of study is to look at the impact of the recent cycles of ENSO and PDO (the last 15 years, 2007-2022) to see if these climate pattern changes have had similar impacts or not. Due to the scope and limited resources for my study, I will be omitting other variables known to impact *A. catenella* blooms such as CO2, salinity, nutrient supply, etc. Involving these variables with my study would be a great future path for research on *A. catenella* dynamics and subsequent shellfish toxicity. For example, looking at how PDO or ENSO influence CO2, salinity, and nutrient supply could provide more insight on future *A. catenella* population dynamics.

1. **Summarize your study design[[2]](#endnote-3). If applicable, identify the key variables in your**

**study. What is their relationship to each other? For example, which variables are you considering as independent (explanatory) and dependent (response)?**

The independent variable is the climate pattern (PDO/ENSO) and the dependent variable is the saxitoxin or paralytic shellfish poisoning (PSP) concentration in shellfish. The shellfish tested for PSP concentration are blue mussels and butter clams. I’ll also be using # of days above 13°C as a categorical variable (independent variable). I’ll be using data from the DOH database for PSP concentrations/temperatures and NOAA for the PDO indices to run correlations and t-tests. The site will be from Sequim, WA where the most reliable data has been taken and where Moore et al., 2010 studied up to 2007. I plan to run the similar tests but closing the gap up to 2022.

1. **Describe the data that will be the foundation of your thesis. Will you use existing data, or gather new data (or both)? Describe the process of acquiring or collecting data[[3]](#endnote-4).**

I will be using existing data from the Department of Health. They monitor marine biotoxins and test shellfish throughout the year so there is a huge database of PSP concentrations throughout the state’s sampling sites. The data consists of shellfish type (blue mussels and butter clams), temperature, date taken, and sample site. This data has been collected weekly since the 1950s. For the PDO/ENSO data, I plan to use climate data from NOAA. This database has an annual index for each year where positive PDO or ENSO index relates to above average SSTs and negative PDO or ENSO index pertaining to below average SSTs. The PDO and ENSO indices are described below.

1. **Summarize your methods of data analysis. If applicable, discuss any specific techniques, tests, or approaches that you will use to answer your research question.**

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**ENSO Index:** SST anomalies averaged over the NINO4 region 5°North–5°South; 160°East–150°West (western most of Nino indices). Total sea surface temperatures (SSTs) also available for this region. Calculated from the Monthly extended reconstructed sea surface temperature (ERSST) V5 (at NOAA/CPC).

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**PDO Index:** The National Centers for Environmental Information (NCEI) PDO index is based on NOAA's extended reconstruction of SSTs ([ERSST Version 5](https://www.ncei.noaa.gov/products/extended-reconstructed-sst)). It is constructed by regressing the extended reconstructed sea surface temperature (ERSST) anomalies against the Mantua PDO index for their overlap period, to compute a PDO regression map for the North Pacific ERSST anomalies. The ERSST anomalies are then projected onto that map to compute the NCEI index.

**The Extended Reconstructed Sea Surface Temperature (ERSST)** dataset is a global monthly analysis of SST data derived from the International Comprehensive Ocean–Atmosphere Dataset (ICOADS). The dataset can be used for long-term global and basin-wide studies and incorporates smoothed local and short-term variations. The NOAA Global Surface Temperature ([NOAAGlobalTemp](https://www.ncdc.noaa.gov/data-access/marineocean-data/noaa-global-surface-temperature-noaaglobaltemp)) product integrates ERSST data with land surface air temperature from the [Global Historical Climatology Network-Monthly dataset](https://www.ncdc.noaa.gov/ghcnm/v3.php) to create integrated surface temperature analyses.

-correlation between PDO index and PSP concentrations in tested shellfish

-correlation/ between ENSO index and PSP concentrations in tested shellfish

-t test between # of days above 13°C and # of closure days due to PSP

-t test between # of days above 13°C and PSP toxicity

-t test between PDO index and # of days above 13°C

-t test between ENSO index and # of days above 13°C

-correlation of temperature with shellfish toxicity

-correlation of temperature over time

-correlation of shellfish toxicity over time

PDO index, ENSO, PSP concentrations in Sequim, WA 2007-2022.

1. **Address the ethical issues[[4]](#endnote-5) raised by your thesis work. Include issues such as risks to anyone involved in the research, as well as specific people or groups that might benefit from or be harmed by your thesis work, perhaps depending on your results. List any specific reviews you must complete first (e.g., Human Subjects Review or Animal Use Protocol Form).**

My thesis work does have implications for the shellfish industry that could potentially impact the industry and people’s livelihood. While the purpose of this research is to further public health science and the protection of people, it’s important to note that people can still be negatively impacted. An example of this would be my research resulting in increased regulation to protect people from toxin exposure. While in general this is good, it also results in less economic opportunities for people in the industry, negatively and directly impacting them.

1. **List specific research permits[[5]](#endnote-6) or permissions you need to obtain before you begin collecting data (e.g., landowner permissions, agency permits).**

My research does not require any permits or special permissions.

1. **Reflect on how your positionality as a researcher could affect your results and how you will account for this in the research process[[6]](#endnote-7).**

I’m intrigued by my research question and believe there is reason to believe it is plausible. Moore et al., 2010 has shown relationships between temperature and shellfish toxicity which I plan to build on. Acknowledging my excitement and accepting the data is the best way to avoid positionality impacting my thesis. While collecting data, running data analyses, etc. it’s important to stay grounded in the science and not what outcome you think could prove statistically relevant.

1. **Provide at least a rough estimate of the costs associated with conducting your research, if any.  Provide details about each budget item so that the breakdown of the final cost is clear.**

No known costs. I have the necessary resources to run statistical analyses in R and the data needed is public and free (Department of Health and NOAA databases).

1. **Provide a detailed working outline of your thesis.**

Introduction

-background information

-problem description

-thesis statement/research question

Alexandrium catenella and Paralytic Shellfish Poisoning

-in depth look at PSP, saxitoxin, and impact

-A. catenella life cycle

-environmental drivers impacting algal blooms (oxygen, sunlight, temperature, turbulence, salinity, CO2)

Pacific Decadal Oscillation and El Nino Southern Oscillation

-PDO description

-El Nino description

-La Nino description

-Influences of PDO and ENSO on weather patterns and anomalies

Data sources/methods

-Department of Health shellfish toxin database

-NOAA database on PDO and ENSO indices

-site in Sequim, WA from 2007-2022

Data Analysis/Results

-correlation/regression between PDO index and PSP concentrations in tested shellfish

-correlation/regression between ENSO index and PSP concentrations in tested shellfish

-correlation/regression between # of days above 13 degrees Celsius and # of closure days due to PSP

-correlation/regression between # of days above 13 degrees Celsius and PSP toxicity

-correlation/regression between PDO index and # of days above 13 degrees Celsius

Correlation/regression between ENSO index and # of days above 13 Degrees Celsius

Discussion

-Implications of results

-Does ENSO and PDO contribute to more HABs and subsequent PSP?

-If so, does regulation or policy change dependent on PDO or ENSO index for shellfish industry?

-Increase in shellfish testing during positive PDO and ENSO years?

-vice versa for negative PDO and ENSO years?

Conclusion

-summary with problem addressed

-what is the solution? Testing/regulation guided by ENSO/PDO index?

-future directions of studies (incorporate more study sites and/or other shellfish toxins)

-future direction of shellfish toxin monitoring and regulation

1. **Provide a specific work plan and a timeline for each of the major tasks in the work plan. Be as realistic and specific as you can at this point, including the deadlines for Spring quarter.**

December:

Read through more literature and add to literature review

January:

Compile and clean all the data from DOH and NOAA

Continue to write and add sections to thesis

Meeting with Tracie and Jerry

Get to know the data and run analyses

Jan 12: Overview, thesis timeline, big project organization/writing

Jan 26: Introduction for peer review

February:

Continue to write and add sections to thesis

Feb 9: Methods for peer review

Feb 23: Literature review for peer review

March:

Continue to add sections and work on sections in thesis

Complete data analyses

Complete data visualizations and interpretations

March 9: Results/Discussion (rough draft) for peer review

April:

Complete draft of thesis and send in for edits

Work on edits

April 6: Results/Discussion (complete) for peer review

April 20: Introduction/Conclusion for peer review

May:

Work on edits

Request to present

May 4: Presentation guidelines and sentence-level revision

May 5: Submit request to present thesis research form

May 18: Practice presentations

May 19: Deadline for presentation form signed by reader (Erin Martin)

June:

Final draft of thesis

Final formatting

Presentation

May 23/25 May 30/June 1: Thesis presentations

June 2: Final draft of thesis due to thesis reader

June 9: Final formatted thesis version due to MES office

1. **Who (if anyone), beyond your MES thesis reader, will support your thesis (in or outside of Evergreen)? Be specific about who they are and in what capacity they will support your thesis. If you are working with an outside agency or expert, be specific about their expectations for your data analysis or publication of results.**

Jerry Borchert and Tracie Barry work in the Shellfish Licensing Office at the Department of Health where they run the Biotoxin Monitoring Program. They are a resource of knowledge in the industry and have already been a huge help in narrowing down my research topic. Their expectations are only for me to complete my thesis, there’s no pressure of a publication.

1. **Provide the 5 most important references you have used to identify the specific questions and context of your topic, help with issues of research design and analysis, and/or provide a basis for interpretation. Annotate these references with notes on how they relate to/will be helpful for your thesis. For any other sources cited in your prospectus in other answers, provide a complete bibliographic citation here as well. Highlighted references are annotated.**

Alpine, Andrea E., and James E. Cloern. 1992. “Trophic Interactions and Direct Physical Effects Control Phytoplankton Biomass and Production in an Estuary.” *Limnology and Oceanography* 37 (5): 946–55. https://doi.org/10.4319/lo.1992.37.5.0946.

Anderson, Donald M. 1998. “[PDF] Physiology and Bloom Dynamics of Toxic Alexandrium Species, with Emphasis on Life Cycle Transitions.” 1998. https://www.researchgate.net/publication/301838910\_Physiology\_and\_bloom\_dynamics\_of\_toxic\_Alexandrium\_species\_with\_emphasis\_on\_life\_cycle\_transitions

This paper was essential for studying and understanding the life cycle of *Alexandrium catenella*. A large section of my paper goes over the life cycle and how each stage (cyst, vegetative cell, etc.) are impacted by environmental and physical factors.

Anderson, Donald M., Allan D. Cembella, and Gustaaf M. Hallegraeff. 2012. “Progress in Understanding Harmful Algal Blooms: Paradigm Shifts and New Technologies for Research, Monitoring, and Management.” *Annual Review of Marine Science* 4 (1): 143–76. https://doi.org/10.1146/annurev-marine-120308-081121.

Anderson, Donald M., Marta Estrada, and Grant Pitcher. 2005. “(PDF) The Comparative ‘Systems’ Approach to HAB Research.” 2005. https://www.researchgate.net/publication/33549722\_The\_Comparative\_Systems\_Approach\_to\_HAB\_Research.

DOH. 2022. “Paralytic Shellfish Poisoning (PSP).” Washington State Department of Health. 2022. https://doh.wa.gov/community-and-environment/shellfish/recreational-shellfish/illnesses/biotoxins/paralytic-shellfish-poisoning.

Dyhrman, Sonya T., Sheean T. Haley, Jerry A. Borchert, Bob Lona, Nicole Kollars, and Deana L. Erdner. 2010. “Parallel Analyses of Alexandrium Catenella Cell Concentrations and Shellfish Toxicity in the Puget Sound.” *Applied and Environmental Microbiology* 76 (14): 4647–54. https://doi.org/10.1128/AEM.03095-09.

This paper looked at the concentration of *Alexandrium catenella* concentration in Cells/L and how that correlated to shellfish toxicity in a region. They found that 71% of the time when *A. catenella* was present in high enough concentration, shellfish toxicity would follow. This finding helped me confirm the variables to use for my statistical analysis. I will be using shellfish toxicity as the dependent variable to test with climate patterns (PDO and ENSO) as the independent variable instead of *A. catenella* cells/L.

Garneau, Marie-Ève, Astrid Schnetzer, Peter D. Countway, Adriane C. Jones, Erica L. Seubert, and David A. Caron. 2011. “Examination of the Seasonal Dynamics of the Toxic Dinoflagellate Alexandrium Catenella at Redondo Beach, California, by Quantitative PCR.” *Applied and Environmental Microbiology* 77 (21): 7669–80. https://doi.org/10.1128/AEM.06174-11.

Moore, Stephanie K., Nathan J. Mantua, Barbara M. Hickey, and Vera L. Trainer. 2010. “The Relative Influences of El Niño-Southern Oscillation and Pacific Decadal Oscillation on Paralytic Shellfish Toxin Accumulation in Northwest Pacific Shellfish.” *Limnology and Oceanography* 55 (6): 2262–74. https://doi.org/10.4319/lo.2010.55.6.2262.

This paper is instrumental for my thesis work. Moore et al. 2010 looked at the role of the Pacific Decadal Oscillation and El Nino Southern Oscillation in shellfish toxicity. sea surface temperatures, and number of days above 13°C. I will be using similar data and statistical analyses to answer the same questions but on a different timeline (2007-2022). They found a relationship between PDO and # of days above 13°C, shellfish toxicity and # of days above 13°C, and between PDO and shellfish toxicity (although this relationship was not significant).

Navarro, J. M., M. G. Muñoz, and A. M. Contreras. 2006. “Temperature as a Factor Regulating Growth and Toxin Content in the Dinoflagellate Alexandrium Catenella.” *Harmful Algae* 5 (6): 762–69. https://doi.org/10.1016/j.hal.2006.04.001.

This is another paper instrumental to looking at the environmental and physical factors influencing *A. catenella*. Essentially, I wanted to look at the factors individually so that I could extrapolate out to climate patterns and trends like the PDO and ENSO. In this study, they found in inverse relationship between temperature and toxin production above 10°C. Essentially, growth and toxin production increases with temperature until 10°C, then it starts to decrease. This has interesting implications with climate change since increases in CO2 is predicted to increase toxin production while temperatures above 10°C is predicted to decreases toxin production. This highlights the complexity of *A. catenella* and shellfish toxicity.

Newman, Matthew, Michael A. Alexander, Toby R. Ault, Kim M. Cobb, Clara Deser, Emanuele Di Lorenzo, Nathan J. Mantua, et al. 2016. “The Pacific Decadal Oscillation, Revisited.” *Journal of Climate* 29 (12): 4399–4427. https://doi.org/10.1175/JCLI-D-15-0508.1.

Newman, Matthew, Gilbert P. Compo, and Michael A. Alexander. 2003. “ENSO-Forced Variability of the Pacific Decadal Oscillation.” *Journal of Climate* 16 (23): 3853–57. https://doi.org/10.1175/1520-0442(2003)016<3853:EVOTPD>2.0.CO;2.

This paper looks at the Pacific Decadal Oscillation and what influences this climate pattern. One of the main factors influencing the PDO is the ENSO which has interesting implications I draw in my paper. For example. the PDO is mostly accepted as a pattern that impacts *A. catenella* and shellfish toxicity while the ENSO is not. But, if the ENSO influences PDO phases then one could surmise the ENSO does indirectly impact shellfish toxicity via its influence on the PDO. This is a convoluted connection, but something to not look over.

Ralston, David K., and Stephanie K. Moore. 2020. “Modeling Harmful Algal Blooms in a Changing Climate.” *Harmful Algae*, Climate change and harmful algal blooms, 91 (January): 101729. https://doi.org/10.1016/j.hal.2019.101729.

Schneider, Niklas, and Bruce D. Cornuelle. 2005. “The Forcing of the Pacific Decadal Oscillation.” *Journal of Climate* 18 (21): 4355–73. https://doi.org/10.1175/JCLI3527.1.

Simon, Nathalie, Anne-Lise Cras, Elodie Foulon, and Rodolphe Lemée. 2009. “Diversity and Evolution of Marine Phytoplankton.” *Comptes Rendus Biologies*, La théorie de Darwin revisitée par la biologie d’aujourd’hui / Darwin’s theory revisited by today’s biology, 332 (2): 159–70. https://doi.org/10.1016/j.crvi.2008.09.009.

Smayda, Theodore J. 1997. “Harmful Algal Blooms: Their Ecophysiology and General Relevance to Phytoplankton Blooms in the Sea.” *Limnology and Oceanography* 42 (5part2): 1137–53. https://doi.org/10.4319/lo.1997.42.5\_part\_2.1137.

Sullivan, James M., and Elijah Swift. 2003. “EFFECTS OF SMALL-SCALE TURBULENCE ON NET GROWTH RATE AND SIZE OF TEN SPECIES OF MARINE DINOFLAGELLATES 1.” *Journal of Phycology* 39 (1): 83–94. https://doi.org/10.1046/j.1529-8817.2003.02094.x.

Tatters, Avery O., Leanne J. Flewelling, Feixue Fu, April A. Granholm, and David A. Hutchins. 2013. “High CO2 Promotes the Production of Paralytic Shellfish Poisoning Toxins by Alexandrium Catenella from Southern California Waters.” *Harmful Algae* 30 (December): 37–43. https://doi.org/10.1016/j.hal.2013.08.007.

Trainer, Vera L, Bich-Thuy L Eberhart, John C Wekell, Nicolaus G Adams, Linda Hanson, Frank Cox, and Judy Dowell. 2003. “PARALYTIC SHELLFISH TOXINS IN PUGET SOUND, WASHINGTON STATE,” 11.

US Department of Commerce, National Oceanic and Atmospheric Administration. n.d. “What Are Plankton?” Accessed November 15, 2022. https://oceanservice.noaa.gov/facts/plankton.html.

Van Dolah, F. M. 2000. “Marine Algal Toxins: Origins, Health Effects, and Their Increased Occurrence.” *Environmental Health Perspectives* 108 Suppl 1 (March): 133–41. https://doi.org/10.1289/ehp.00108s1133.

Wells, Mark L., Vera L. Trainer, Theodore J. Smayda, Bengt S. O. Karlson, Charles G. Trick, Raphael M. Kudela, Akira Ishikawa, et al. 2015. “Harmful Algal Blooms and Climate Change: Learning from the Past and Present to Forecast the Future.” *Harmful Algae* 49 (November): 68–93. https://doi.org/10.1016/j.hal.2015.07.009.

1. You are not locked into this title; we want you to identify the main point or topic of your thesis. [↑](#endnote-ref-2)
2. You might discuss selection of case studies, sampling methods, experimental design, and/or specific hypotheses you will test. You should also address any specialized knowledge or skills that are necessary to complete the research. [↑](#endnote-ref-3)
3. If you are planning to use existing data, explain the specific source, contact information, arrangement with collaborating agencies, and expectations about use of data and final products of your research. If you are planning to gather new data, describe specific methods, time, place, and equipment that will be required. [↑](#endnote-ref-4)
4. If you’re not sure where to start, consult a ‘Code of Ethics’ or other similar document from an academic society in an applicable field of study. [↑](#endnote-ref-5)
5. If you are collecting ANY samples or data, even observational data, on public lands (city, county, state and/or federal) it is your responsibility to find out the permit requirements BEFORE you collect data. Conducting research with tribal members/on tribal lands will have different and additional requirements. [↑](#endnote-ref-6)
6. Your *positionality as a researcher* refers to the fact that one’s “…beliefs, values systems, and moral stances are as fundamentally present and inseparable from the research process as [one]’s physical, virtual, or metaphorical presence when facilitating, participating and/or leading the research project…” (The Weingarten Blog 2017). [↑](#endnote-ref-7)