The Evergreen State College
Graduate Program on the Environment
Thesis Prospectus

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STUDENT AGREEMENT:

SIGNATURE: _____ **DATE**_____

FACULTY READER APPROVAL:

SIGNATURE: _____ **DATE**_____

MES DIRECTOR APPROVAL:

SIGNATURE:_____ **DATE**_____

1) **Provide the working title of your thesis[i].**
The interplay of native eelgrass (*Zostera marina*) and Olympia Oysters (*Ostrea lurida*): exploring interspecies relationships and co-restoration in the face of climate change

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

Recent restoration efforts for the Olympia oyster (*Ostrea lurida*) in Puget Sound are motivated by economic value and the potential return of oyster-associated ecosystems services. The potential impact of restoration efforts on another species of ecological concern, eelgrass (*Zostera marina*), is unclear. Co-restoration of the two species has been hypothesized to be positive along the west coast of the United States, but results based on a handful of studies in Puget Sound remain inconclusive. As climate change continues to expose nearshore habitats to detrimentally changing oceanographic conditions, restoration efforts need to adapt to best suit what's to come as climate change becomes more of a reality in Puget Sound.

3) State your research question(s).

-How do the ecosystem services *Zostera marina* and *Ostrea lurid*a provide influence their symbiotic relationship? How do they interact under stressors of climate change?
-Do the species habitat suitabilities overlap in Puget Sound?
-Would there be ecological benefits to co-restoration if socio-economic pressures were overcome?

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

Both *Z. marina* and *O. lurida* are high focus species in Puget Sound and provide many ecosystems services. Eelgrass plays a huge role in habitat structure (Blake and Bradbury, 2012; Thom et al., 2007), while oysters are equally as ecologically valuable while also acting as an economic driver in Washington State (Baker, 1995). As climate change and ocean acidification continue to worsen, both important species are at risk of detrimental loss and have already experienced declines in population (Heare 2014; Mumford et al., 2007). These declines have led to large sums of money invested towards research and restoration of each of these species individually (Thom et al., 2007). Current and previous literature suggest that there may be a symbiotic relationship between oysters and eelgrass, as both species have the potential to utilize the qualities and ecosystem services of one another for their own benefit (Valdez et al., 2017). For example, shellfish filter seawater which can result in greater light penetration and can in turn be beneficial to eelgrass which depend on high light availability for survival, especially as sea level rise persists in Puget Sound. Recent studies also suggest that eelgrass can ameliorate effects of ocean acidification by increasing pH, in turn benefiting shellfish that rely on higher pH for shell building while in development stages (Valdez et al., 2017). Despite restoration being a priority for both species in Puget Sound, little information in known about how these two species interact under stressors of changing ocean conditions, and the restoration potential of restoring them simultaneously into the future. This study aims to identify how the species utilize the ecosystem services provided by one another under stressors of climate change, and if there is potential to restore each population in conjunction.

5) 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?

This research is important because in the face of climate change, our nearshore marine environments and critical species are at risk and face detrimental decline (Heare 2014; Mumford et al., 2007). Shellfish and eelgrass beds act as a critical habitat for numerous nearshore species and are incredibly valuable to the marine and estuarine environment. Understanding the relationship between eelgrass and shellfish could reveal important information about habitat similarities, mutual climate adaptation strategies, and species characteristics that could give restoration managers more information to better decide how to prioritize marine nearshore restoration and climate mitigation plans (Groner et al., 2018).

6) Summarize your study design[ii]. 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)?

To describe my study design, I broke each step into parts, identifying how each step will be prioritized. My goal is to understand the relationship between native eelgrass and oysters better, particularly in the face of warming and acidifying ocean conditions. I will use current population data alongside biological species interaction data to examine if co-restoration is a viable or useful possibility. I then weigh those interactions against environmental parameters taken over a 6-year period. If time permits, I hope to strengthen my argument by addressing and evaluating current restoration successes and failures in greater Puget Sound for each species.

a) Goal/Objective: To understand current/most up-to-date population distribution of *O. lurida* & *Z. marina* in Puget Sound

Variable	***Data***	***Method***
Ostrea lurida population in Puget Sound	WDFW shellfish population distribution survey datasets 2020/2021	-Utilize population locations database to map in ArcGIS where *O. lurida* populations are found currently in Puget Sound
Zostera marina population and distribution in Puget Sound	WDNR Nearshore Aquatic Team- eelgrass population distribution survey dataset	-Utilize population locations database to map in ArcGIS where where Z. marina is found currently in Puget Sound
Overlapping populations map	*O. lurida* & *Z. marina* maps of population distribution	-Overlay spatial population maps and assess overlapping areas through geospatial analysis tools

Purpose/Outcome:
The purpose of identifying where each species current population resides is to ultimately see where overlap of the two species is occurring.

b) Goal/ Objective: Evaluate recent Habitat Suitability Models (HSM) for *O. lurida* and *Z. marina* to curate a list of areas where proposed habitat suitability of each species overlaps.

Variable	***Data***	***Method***
Habitat Suitability Model/Index- *Ostrea lurida*	Habitat Suitability Index- Puget Sound Restoration Fund 2020	-Identify variables used and compare -Compare Models
Habitat Suitability Model- *Zostera marina*	Habitat Suitability Model- WDNR Nearshore Habitat	-Identify variables used and compare

	(last updated: 2020)	-Compare Models

Purpose/Outcome:
The purpose of evaluating these Habitat Suitability Models is to understand not only what variables are important to identify critical habitat characteristics for each species, but to determine where or if there is overlap between the two species.

c) Goal/Objective: Utilize data that was collected across Puget Sound to identify benefits of growing oysters within, and near eelgrass, while also comparing to similar data growing oysters in bare patches of sediment. Utilize shellfish recruitment data to understand further if shellfish larvae are more likely to recruit to eelgrass habitat or bare habitat types. Utilize environmental in-situ water quality data collected simultaneously to determine if eelgrass ameliorates effects of ocean acidification.

Variable	***Data***	***Method***
Oyster Growth	-*O. lurida* growth data inside vs outside eelgrass beds (WDNR ANeMoNe: Aquatic Nearshore Monitoring Network)	-Comparative analysis of Olympia Oyster growth inside vs outside eelgrass beds
Oyster Recruitment	-*O. lurida* larvae recruitment inside vs outside eelgrass beds (WDNR ANeMoNe)	-Comparative analysis of Olympia Oyster larvae recruitment inside vs. outside eelgrass beds
Eelgrass vs bare habitat water parameters	-In-situ environmental water parameter data: pH, DO, Salinity/Conductivity, Temperature, Chlorophyll a (WDNR ANeMoNe; PRISM?)	-Compare eelgrass vs bare environmental water parameters & overlay with concurrent oyster recruitment and oyster growth data

Purpose/Outcome:
To better understand the interaction between the two species. Including environmental data will not only shed light into how the nearshore environment has been changing, but if there is a significant difference between eelgrass habitats vs unvegetated/ bare habitats.

d) Goal/Objective: (If time permits) To evaluate *Z. marina* and *O. lurida* restoration successes and failures in Puget Sound.

Variable	***Data***	***Method***
O. lurida restoration attempts	-Oly Oyster documented restoration efforts in Puget Sound (Puget Sound Restoration Fund, WDFW)	-Compile list of all documented restoration efforts & determine success of restoration, if available -Compile list of why restoration efforts were and

		were not successful
Z. marina restoration attempts	-Z. marina documented restoration efforts in Puget Sound (WDFW)	-Compile list of all documented restoration efforts & determine success of restoration, if available -Compile list of why restoration efforts were and were not successful

Purpose/Outcome:
I hope to qualitatively evaluate restoration success in Puget Sound for both species, to better identify what has already been done, and what is being done to address unsuccessful restoration efforts.

7) **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[iii].**

In this study, I will not be collecting new data, but instead be using existing data, including data that I have helped collect previously.

The foundation of this study will hinge on current *O. lurida* and *Z. marina* population data made publicly available through Washington Department of Fish and Wildlife, as well as Washington Department of Natural Resources. Because both agencies are primary researchers for each species, ample public data is available on current population status. As described in the tables above (question 7), alongside current population data, I will be utilizing one habitat suitability model (HSM) for each species. Department of Natural Resources Aquatics Department developed an HSM for *Z. marina* in 2018, describing and identifying ideal habitat for eelgrass (*Z. marina* specifically) across Puget Sound. Puget Sound Restoration Fund in 2020 also developed a habitat suitability index (HIS) for *O. lurida* similarly identifying ideal habitat for oysters.

I will also utilize data that I have helped collect at Department of Natural Resources, with the Aquatic Assessment and Monitoring Team. This data will be sourced from the Aquatic Nearshore Monitoring Network (ANeMoNe), which has accumulated in-situ environmental monitoring data since 2015 at 10 different geographically spread locations throughout Puget Sound. Alongside environmental monitoring data, I will utilize the biological oyster recruitment and growth experiment data collected simultaneously at a variety of the ANeMoNe sites since 2015.

Lastly, (if time permits) I will utilize reports from Puget Sound Restoration Fund and WDFW to compile a list/table of *Z. marina* and *O. lurida* restoration efforts in Puget Sound and assess success and failure of each restoration attempt.

I am fortunate to currently hold a WDNR agency position, with access to data that is not yet publicly available or published. Utilizing this data is a privilege, and consulting with my work

peers will be a priority. In regard to accessing data that is not yet publicly available from both WDFW and PSRF, emails and zoom calls have and will continue to be my primary form of contact to gain access to information I am seeking.

8) **Summarize your methods of data analysis. If applicable, discuss specific techniques that you will use to understand the relationships between variables (e.g., interview coding, cost-benefit analysis, specific statistical analyses, spatial analysis) and the steps and tools (e.g., lab equipment, software) that you will take to complete your analyses.**

In order to assess if eelgrass and oysters currently utilize similar habitats, I will start by spatially identifying current populations of both species in Puget Sound. I will utilize current population data available to spatially compare populations. I will utilize ArcGISPro (and likely Mike Ruth) to display each species population distribution and overlay them to make comparisons.

In order to determine further if *O. lurida* and *Z. marina* share habitat suitability, I will compare variables used in habitat suitability models, and outcome from habitat suitability models. I will compile a chart, and/or table to help categorize similarities and differences.

In order to identify benefits of growing *O. lurida* and *Z. marina* together, I will statistically compare oyster growth and recruitment data inside and outside of eelgrass beds. I will utilize RStudio to clean up data to make comparisons, and then determine what statistical analysis to run to determine the significant difference between eelgrass and bare sites.

Lastly, I will analyze restoration efforts for both species and collate a table that displays what efforts have been made, and where. I will then determine % of success and failure of restoration efforts.

I think it would be interesting to include cost of restoration efforts, and compare that to rate of success/failure, if time and data availability permits.

9) **Address the ethical issues[iv] 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).**

Although I will do my best to remain unbiased and informed when interpreting peer-reviewed literature and analyzing data that is not my own, I recognize that there may be ethical issues when pursuing a topic of climate change and land categorization. I recognize that while interpreting data, I may interpret trends, data gaps, or results that do not coincide with the beliefs of the organizations sourcing the data. I also recognize that some results from land categorization may not coincide with beliefs of a private entity or organization and cause a discrepancy. I hope that this research, despite the outcome, could help inform further land protections and restoration efforts. I will do my best to ensure accuracy of research, so misguided decisions aren't made in the future. I will do my best to cover all bases with a thorough literature review, and with

truthful, open research discussion with advisors, peers, and cohort members.

10) List specific research permits[v] or permissions you need to obtain before you begin collecting data (e.g. landowner permissions, agency permits).

I will not be collecting my own data for this research. The environmental and biological data I intend to utilize is going to be sourced from both public and private entities (i.e. Department of Natural Resources, Department of Fish and Wildlife, Puget Sound Restoration Fund). Where permission is required to access data, I will navigate acquiring it respectfully and formally, asking for permission. Fortunately, public data is available and will be foundational for this research. When formal discussion and data requests are necessary, I will ensure there are conversations about expectations and data sharing requirements.

11) Reflect on how your positionality as a researcher could affect your results and how you will account for this in the research process[vi].

Growing up in the privileged position that I did, I was granted the opportunity to prioritize natural science education and invest my time into marine science. Because of these privileges, I recognize that as an environmentalist, I may expect outcomes based on my prior understanding of natural systems and in turn, bias how I look at the data I acquire. Through open discussion with cohort members, advisors, and coworkers, I will ensure other voices will have an opportunity to share thoughts and perspectives on my understanding and findings.

12) Provide at least a rough estimate of the costs associated with conducting your research. Provide details about each budget item so that the breakdown of the final cost is clear.

This research will have no cost- except that of my own time.

13) Provide a detailed working outline of your thesis.

1.Title Page
- a) The interplay of native eelgrass (*Zostera marina*) and Olympia Oysters (*Ostrea lurida*): exploring interspecies relationships and co-restoration in the face of climate
- b) Name + affiliation

2.Acknowledgements

3.Abstract
- c) Summary of Research

4.Table of Figures
- d) Maps
- e) Tables
- f) Charts, etc

5.Table of Contents
- g) Introduction
- h) Literature Review

i) Methods
j) Results
k) Discussion
l) Conclusion
m) Citations/References
n) Appendix?

6.Literature Review

o) Introduction
p) Puget Sound Nearshore Environment
    i) History
q) Olympia Oysters (O. lurida)
    i) Brief History
    ii) Distribution in Puget Sound
    iii) Ecosystem Services
    iv) Climate Stressors
    v) Restoration Efforts
r) Eelgrass (Z. marina)
    i) Brief History
    ii) Distribution in Puget Sound
    iii) Ecosystem Services
    iv) Climate Stressors
    v) Restoration Efforts
s) Eelgrass + Oysters
    i) Symbiosis
    ii) Experimental Testing
    iii) Pilot Study Restoration Efforts
    iv) Research Gaps
t) Conclusion
    i) Research suggestions
    ii) Big picture summary

7.Methods

u) Understand current/most up-to-date population distribution of *O. lurida* & *Z. marina* in Puget Sound
v) Evaluate recent Habitat Suitability Models (HSM) for *O. lurida* and *Z. marina* to curate a list of areas where proposed habitat suitability of each species overlaps
w) Utilize data that was collected across Puget Sound to identify benefits of growing oysters within, and near eelgrass, while also comparing to similar data growing oysters in bare patches of sediment. Utilize shellfish recruitment data to understand further if shellfish larvae are more likely to recruit to eelgrass habitat or bare habitat types. Utilize environmental in-situ water quality data collected simultaneously to determine if eelgrass ameliorates effects of ocean acidification.
x) Evaluate *Z. marina* and *O. lurida* restoration successes and failures in Puget Sound.

8.Results

y) Maps of spatial populations
z) Tables of findings from habitat models addressing similarities, differences
aa) Figures/graphs of statistical analysis of environmental and biological data

bb) Table of restoration success and failures

9.Discussion

cc) Deep dive of findings discussion

dd) Address problems with research and data limitations

ee) Address what could have been done and gaps in data

10.Conclusion

ff) Address research gaps

gg) Make suggestions for future research and restoration

11.Citations/References

hh) Formatted appropriately

14) Provide a specific work plan and a timeline for each of the major tasks in the work plan. Be as realistic as you can, even though you will probably need to alter this schedule as you complete the tasks. Remember that faculty readers take time to return your drafts and that the final polishing and formatting of your thesis for binding will take longer than you ever imagined.

~~**October/November**: Begin acquiring data, contacting outside entities~~
~~**November 16th**: Thesis Abstract due~~
~~**November 18th**: Literature Review draft due~~
~~**December 2nd**: Last draft of prospectus due~~
~~**December 7th**: Final Poster due~~
~~**December 9th**: Poster presentation~~
December 10th: Thesis Prospectus submitted to MES, signed by faculty reader

- Continue work on methodology and study design

Take some break time to relax and regroup!
December 20th: Have data acquired
Winter break: Finalize methodology and study design and submit for feedback

- Data cleaning
- Finalize literature review
- Work on Introduction

January 15st: Data cleaning and formatting

- Begin data comparisons/work in ArcGIS/spatial analysis with Mike Ruth
- Submit introduction and literature review for feedback

January 30th: Continue work on data cleaning and preliminary evaluation of data
February 15th: Begin deeper analysis & work with reader to assess what statistical tests should be run

- Continue editing and writing all work

February 28th: Begin configuring versions of maps, figures, and tables

- Begin writing results and discussion
- Start thinking about the conclusion
- Send more finalized draft of Intro, Lit Review, Methods for review
- Start making formatting edits and ensuring citation coherency

March 15th: Send draft of results and partial discussion for review

- Continue writing discussion

- Continue writing conclusion
- Continue making edits
- Continue working through data and figures

Take some break time to rest and relax

April 4th: First full (more finalized) draft to faculty advisor

- Continue making edits to writing and making additions to figures and tables
- Request to present
- Begin working on presentation

April 15th: Update results and figures as necessary

- Continue making edits based on feedback
- Make sure formatting is coming together
- Read throughs of all sections for coherency

May (beginning/middle): Present results (in person?)

Take a little break as a reward for presenting research!

May 20th: Final draft to faculty advisor

- Final edits and read throughs
- Finalize and update figures to ensure coherency & details are in place
- Ensure formatting is concise
- Write acknowledgments

By June 10th: Submit Final copy of thesis to MES office

15) **Who, beyond your MES faculty reader, will support your thesis? Indicate support both within and 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.**

I will be working with the Department of Natural Resources Aquatic Assessment and Monitoring Team to complete this work. There are expectations for me to utilize unpublished data from the Aquatic Nearshore Monitoring Network (ANeMoNe), and to write a technical style report at the completion of my thesis, as well as present preliminary findings at an ANeMoNe symposium in Spring of 2022. I imagine my supervisor at DNR (Cinde Donoghue) will help with providing context around project research design to help guide some statistical analysis.

16) **List the 3-5 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. For each annotated reference, explain how your project specifically connects to the source by extending, challenging, or responding to the conclusions, methods, or implications. For any other sources cited in this document provide a complete bibliographic citation.**

Blake, Brady, and Alex Bradbury. “Washington Department of Fish and Wildlife Plan for Rebuilding Olympia Oyster (Ostrea Lurida) Populations in Puget Sound with a Historical and Contemporary Overview,” n.d., 26.

This report produced by Department of Fish and Wildlife was a catalyst of its time, highlighting the importance of Olympia Oyster Restoration and identifying 19 priority areas for researchers and restoration agencies to focus on Olympia oyster restoration efforts. The paper begins by giving an in-depth description of oyster life history in Puget Sound, ecosystem services they provide, and reasoning for prioritizing restoration efforts. This report is significant for my research because it highlights area of focus but has also been a steppingstone for much of the restoration work taking place around Olympia oysters in Puget Sound right now. Despite it being slightly outdated, there is critical information provided that is helping guide my thought process, study design, and methodology. I hope to expand on the work of this paper by providing further information about Olympia oyster ecosystem services in conjunction with another species.

Mumford, Jr and Thomas F. "Kelp and Eelgrass in Puget Sound:" Fort Belvoir, VA: Defense Technical Information Center, May 1, 2007. https://doi.org/10.21236/ADA477318.

This report was produced by the leading marine aquatic vegetation expert of their time and covers crucial information about aquatic vegetation in Puget Sound. This report has guided me through my literature review, proving information on life history of native eelgrasses and covering many of the ecosystem services they provide.

Valdez, Stephanie R., Betsy Peabody, Brian Allen, Brady Blake, and Jennifer L. Ruesink. "Experimental Test of Oyster Restoration within Eelgrass: Oyster Restoration in Eelgrass." *Aquatic Conservation: Marine and Freshwater Ecosystems* 27, no. 3 (June 2017): 578–87. https://doi.org/10.1002/aqc.2722.

This peer-reviewed piece of literature has helped guide my study design. This study examines on a very small scale in Hood Canal, growing eelgrass and Olympia oysters in proximity of one another under the guise of oyster restoration. They had no significant findings but argued that their study may have been on too small of a scale to have any conclusive findings. I think this paper is interesting, and one of the only tests of co-restoration of these two species in Puget Sound. Because of the inconclusive findings here, and few studies like it in the Pacific Northwest, I am eager to expand on this research and make the argument that more research like this needs to happen before making an conclusive statements. I hope to expand on this research through my study, and potentially make the argument that more co-restoration experiments similar to this need to happen in order to adequately make restoration decisions in Puget Sound.

Thom, RM, JL Gaeckle, KE Buenau, AB Borde, J Vavrinec, L Aston, and DL Woodruff. "Eelgrass (Zostera Marina L.) Restoration in Puget Sound: Development and Testing of Tools for Optimizing Site Selection," n.d., 62.

This paper, by Department of Natural Resource scientists, uses dozens of marine environmental and biological variables to create a large scale model that projects where the most crucial areas to restore eelgrass in Puget Sound are. The scientists here use historical eelgrass population data, biomass survey data, environmental parameters, sea level rise projections, among many others to display notable restoration sites. The don't define these potentially successful restoration areas as "refugia" per say, but they identify areas where eelgrass may be the most resilient based on projections of future climate change. This paper is critical to my research, as it outlines

restorations sites based off an impressive number of variables. I hope to use this data paired with oyster habitat models to determine overlap of suitable habitat. Expanding off their work could further aid in restoration prioritization.

Citations

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[i] You are not locked into this title; its purpose is to help you identify the main point or topic of your thesis at an early stage.

[ii] 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.

[iii] 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.

[iv] 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.

[v] 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.

[vi] 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).