

Navigating the Regulatory Barriers to Native Oyster Restoration in
Washington State: A Decision Analysis Approach

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Abstract

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The Olympia oyster (*Ostrea lurida*) has been the focus of restoration efforts in Washington State for decades. Many biological and ecological factors contribute to the success of oyster restoration projects, and there is a wide range of information available to restoration project managers who want to take these factors into consideration when planning new restoration sites. However, less information exists on the regulatory factors which contribute to the early success of Olympia oyster restoration projects. The complex permitting system which surrounds shellfish aquaculture in Washington places a regulatory burden on oyster restoration projects, and makes it difficult for new projects to begin in an efficient and timely manner. In this thesis, I perform a decision analysis using Analytic Hierarchy Process (AHP) to determine which of several alternative permitting pathways would best reduce the regulatory burden on

Olympia oyster restoration projects. The goal of this analysis is to provide basic permitting strategy recommendations for county-level restoration groups and a model with which they can quantitatively examine criteria and alternatives related to permitting pathways for shellfish aquaculture in Washington. Using this decision analysis method, I found that strategies such as partnering with previously-permitted shellfish aquaculture sites and requesting permit exemptions can reduce the regulatory burden on oyster restoration projects by minimizing the number of permits required, the time required for permits to be approved, and the costs associated with lengthy and complex permitting processes.

Introduction

Environmental restoration is a complex process, and many factors contribute to the success of restoration projects (Bayraktarov et al., 2016). Between the many biological and ecological factors relevant to any restoration project, planners must be careful when determining which are the most important for their goals. For many restoration projects, there is a wealth of background information and research already available to assist in determining the best choices for the biological and ecological aspects of the system (Jones et al., 2018). By using this information prior to beginning restoration, planners are able to increase the likelihood that their projects will be successful (Bayraktarov et al., 2016).

Although there is often biological and ecological analysis for organisms targeted for restoration projects, there is relatively little analysis done with regard to the regulatory systems which govern restoration projects (Jones et al., 2018). As regulatory factors often play a key role in the planning process for restoration projects, it is beneficial for planners to give thought to the management frameworks and permitting processes which surround their target ecosystems. While biological and ecological factors are crucial to the long-term success of restoration projects, choosing an appropriate strategy for navigating regulatory systems may improve the early success of restoration projects.

This thesis will present a brief overview of the state of Olympia oyster restoration in Washington State, followed by an explanation of environmental decision analysis, a description of the Analytic Hierarchy Process, and the application of this decision analysis framework to the issue of obtaining Olympia oyster restoration. I also describe the methods by which I identified relevant criteria for choosing an alternative permitting pathway for Olympia oyster restoration

projects. Finally, I discuss the implications of this decision analysis for future Olympia oyster restoration projects.

The Olympia Oyster (*Ostrea lurida*)

The Olympia oyster (*Ostrea lurida*) is a prime example of a restoration target where regulatory frameworks play an important role in early project success (i.e., completing all of the regulatory and preparatory steps necessary to start implementing an oyster restoration project). As the only native oyster on the West Coast of North America, the Olympia oyster has become a focus for restoration efforts in the last twenty years (Peter-Contesse and Peabody, 2005). Oyster reefs are the most endangered marine habitat globally, and research suggests that oyster reefs can provide a unique suite of ecological functions (Beck et al., 2011). While Olympia oysters are not reef building like other oyster species, established Olympia oyster beds can enhance water quality and provide habitat for juvenile fish and invertebrates (Peter-Contesse and Peabody, 2005). Although they were once abundant between British Columbia and Baja California, Olympia oyster populations are approximately 4% of their historic maximum (Peabody and Davis, 2013). Multiple projects have been implemented in Washington State to increase Olympia oyster populations within its historical range.

Oyster restoration project design varies depending on the target habitat and desired outcomes. Methods range from spreading oyster shell to increase natural settlement of oyster larvae to spreading seed oysters on beaches (Wasson et al., 2015). Other projects include oyster restoration as part of the process of building living shorelines to improve coastal resilience (NOAA Fisheries, 2017). Reports giving details on individual projects and general

information about Olympia oyster restoration exist, but there is a noticeable lack of guidance regarding regulations, permitting, and project design (Wasson et al., 2015).

Shellfish Permitting in Washington State

Restoration efforts for the Olympia oyster face multiple biological and ecological barriers to success. In Washington, these include loss of habitat due to shoreline development, impaired water quality, and lack of natural larval supply (Blake and Ermgassen, 2015). However, the regulatory framework for shellfish restoration in Washington also creates a region-specific barrier to project success (Lund and Hoberecht, 2016). Shellfish permitting in Washington is primarily based on commercial shellfish aquaculture, such as oyster farms or mussel rafts. Furthermore, the permitting framework itself was designed for shoreline development in general (Lund and Hoberecht, 2016). These two facts make it challenging for restoration practitioners to obtain permits in Washington, as the permitting pathway is not fitted to the attributes of oyster restoration projects (Lund and Hoberecht, 2016). The Shellfish Interagency Permitting Team has developed guidance documents aimed at reducing confusion for shellfish permit applicants (Lund and Hoberecht, 2016).

Permit	Agency	Required for all projects
Hydraulic Project Approval (HPA)	WDFW	Yes
Department of the Army Permit*	U.S. Army Corp of Engineers	Yes
Aquatic Lands Lease	WDNR	No, only required for projects sited on state-owned aquatic land
Shoreline Conditional Use Permit	County Government	No, only required in some counties
Shellfish Transport Permit	WDFW	No, only required if shellfish, seeded cultch, or shell is transported from outside the restoration site area

Table 1: A list of the permits required for oyster restoration projects in Washington State. Some permits are only required under certain circumstances, such as when a project takes place on state-owned aquatic lands. This list excludes permits required for commercial shellfish farms where shellfish are harvested for human consumption. *Some oyster restoration projects may qualify for Nationwide Permit 27 for Aquatic Habitat Restoration, Establishment, and Enhancement Activities, from the Army Corps of Engineers but this thesis does not discuss the process for approval under nationwide permits.

All shellfish projects in Washington require permits from multiple agencies. Table 1 lists all of the permits which are required for an oyster restoration project in Washington, as well as the associated permitting agencies. These include the Washington State Department of Fish and Wildlife (WDFW), Washington State Department of Natural Resources (WDNR), and the U.S. Army Corps of Engineers. County and local governments often require additional permits beyond those required by the state and federal governments. Commercial shellfish operations require additional harvest permits from the Washington State Department of Health, and private landowners who harvest shellfish from their properties must enter agreements with tribal groups to allocate half of the available shellfish for tribal harvest (“United States v. State of Wash., 898 F. Supp. 1453 (W.D. Wash. 1995),” n.d.). This harvest allocation also applies to state-owned aquatic lands which are leased by the WDNR. Except for harvest-related permits,

oyster restoration projects must obtain all of the same permits required for commercial shellfish projects. Additionally, restoration projects must obtain a Hydraulic Project Approval (HPA) permit from WDFW, which is not required of commercial shellfish farms (WAC 220-660-040). Conditional use permits are issued at the county level if required. They serve to regulate shoreline development in coastal counties, and conditional uses are defined in each county's Shoreline Management Program ("Shoreline Conditional Use Permit," 2018). Regional differences for shellfish permits arise when different counties define shellfish aquaculture or restoration differently in their Shoreline Master Programs.

Rather than applying separately to each of these organizations, oyster restoration project managers use the Joint Aquatic Resources Permit Application (JARPA), which allows individuals or organizations to apply for more than one environmental permit at a time ("One-Stop JARPA Resource Center," 2018). Even with the JARPA system to reduce redundancy in the application process, Washington State government has recognized the difficulty in coordinating the permitting process between multiple agencies. As part of the Washington Shellfish Initiative, the Shellfish Interagency Permitting (SIP) team was developed in 2011 to improve the efficiency of the permitting process while ensuring shellfish projects meet regulatory requirements (Lund and Hoberecht, 2016). The SIP team released a summary of the commercial shellfish application process, which is shown in Appendix A. This flowchart describes the permitting process for commercial shellfish projects as of 2014, and while some of the items on the chart do not apply to the oyster restoration framework, the complexity of the two processes is comparable. Because this framework was not specifically designed for the needs of either shellfish

aquaculture or environmental restoration, difficulties arise when project managers navigate the process for oyster restoration.

Barriers to Restoration Project Success

The SIP team and others have identified the complex regulatory process for shellfish permits in Washington as a significant barrier to starting new shellfish projects. Because nearly the same process applies to native oyster restoration, the delays, uncertainty, and costs associated with obtaining these permits present barriers to the early success of restoration projects. Permit requirements vary depending on county and municipal requirements, so there is no single permitting process for the state. The initial steps in the planning process for oyster restoration are determining which permits are required and estimating the timeline and cost for obtaining the permits. The SIP team recommends that project managers meet with representatives of the permitting agencies with which they need to work before beginning the application process in order to confirm permitting requirements, costs, and timelines (Lund and Hoberecht, 2016).

Following the recommended JARPA application process, the current estimated timeline for acquiring the necessary permits for oyster restoration projects ranges from three months to one year depending on the complexity of the project, the timelines of local permitting agencies, and whether there is a public comment period (Evrard, 2017). Costs associated with permit applications, and thus the cost of restoration, can quickly mount in this period of time due to the need to maintain staff, collect data, or work on other aspects of the project. While most projects are eventually approved, the uncertainty faced by managers in waiting for the JARPA form to be approved by all of the necessary agencies is exacerbated in counties which have

greater scrutiny placed on shellfish projects in general. Even though shellfish permitting is a statewide process, regional differences such as conditional use permits can add more complexity to the permitting process, as described above.

Analysis of Environmental Decision-Making

Decision analysis is a powerful tool with many applications in environmental management. (Linkov and Moberg, 2017). Because environmental problems are complex, they typically require collaboration between multiple managers, stakeholders, and agencies. Increasing the number of stakeholders in a decision process can lead to conflicting priorities within the permitting process, so it is beneficial for project decision-makers to implement an analytical approach to complex decision processes like obtaining Olympia oyster restoration permits.

There are many approaches to decision analysis, but the goal of all decision-making tools is to improve the quality of the decision process. Decision analysis does not reveal the “right answer”, but rather it recommends an answer based on decision makers’ preferences and assumptions framing the decision (Clemen, 1996). One quality which makes decision analysis a good tool for environmental decision-makers is its ability to clearly define the process by which a policy or action is chosen. For projects like oyster restoration which often utilize public funds or grants, transparency and accountability are critical in the planning process (Drew, 2004).

For Olympia oyster restoration permits, there is a question of what the decision alternatives could be. There is no way to fully avoid the permitting process, and in fact regulatory and bureaucratic processes are generally necessary to avoid many major environmental problems (Mitchell, 2010). However, there are ways to navigate the permitting process in a way which reduces the number of permits and time required to start an oyster restoration project in

Washington without circumventing the environmental protections this process protects. This thesis explores the decision of which method of reducing the regulatory burden is the best alternative.

The first step in the decision analysis process is to identify the decision-maker. The case investigated here will center on county-level restoration projects in Washington, because much of the variation in the permitting process occurs at this level. With this in mind, the hypothetical decision-maker is the manager of a county-level Olympia oyster restoration project. Second, one must define three features of the decision: the objective, the alternatives, and the criteria influencing the decision. In the case of county-level Olympia oyster restoration project managers in Washington, the fundamental initial objective is to find the path of least resistance through the shellfish permitting process. The rationale for achieving this objective centers on reducing the regulatory burden for oyster restoration projects.

Methods for Decision Analysis

After defining the decision maker and objectives, one can next determine the appropriate decision analysis tool for the problem. The types of criteria and level of expertise in decision analysis both play a role in choosing an analytical method (Clemen, 1996). A decision analyst can be considered an expert if they are well-versed in the field of the problem being analyzed, or an analyst can choose third party experts from that field (Clemen, 1996). The analyst or other experts work with the decision maker to identify the available decision alternatives and the criteria which are important to the decision (Linkov and Moberg, 2017). Criteria can be quantitative measures, like cost, or qualitative measures, like certainty. One issue which often arises, particularly in environmental decisions, is the lack of consistency in the types of criteria

considered for decisions. There are normalizing methods to put multiple types of measurements on the same scale, but this does not always work when a criterion is difficult to operationalize from the outset (Linkov and Moberg, 2017). An example of this could be a measure like efficiency, which can be measured in many different ways and varies between projects. One group of methods which has been developed specifically for this type of decision is Multi-Criteria Decision Analysis (MCDA) (Linkov and Moberg, 2017). MCDA refers to several methods which analyze complex decisions with multiple criteria and alternatives. All MCDA methods are characterized by their ability to break complex decisions into smaller, simpler decisions and reintegrate those smaller decisions into the final recommendation (Linkov and Moberg, 2017).

For the Olympia oyster restoration case, I selected a type of MCDA known as Analytical Hierarchy Process (AHP) (Saaty, 1980). AHP lends itself to the decisions faced by restoration project leaders when faced by multiple permitting pathways when there are clear preferences between the criteria which inform the decision. AHP is based on a series of pairwise comparisons for the decision criteria, followed by pairwise comparisons of the decision alternatives with respect to each criterion (Saaty, 1980). The criteria and alternatives are weighted on a 1 through 9 scale of preference (shown in Table 2), with 1 being no preference and 9 being a strong preference for one option. The reciprocal score is assigned if the latter criterion is preferable to the former. For example, if one compared two criteria, A and B, and A was strongly preferable, that comparison might score a 7. If B was strongly preferred to A, however, the score would be 1/7. The pairwise comparisons for decision alternatives with respect to each criterion follows the same method.

RATING	RECIPROCAL	DEFINITION
1	1	Equally preferred
2	1/2	Weak preference
3	1/3	Moderate preference
4	1/4	Moderate to strong preference
5	1/5	Strong preference
6	1/6	Strong to very strong preference
7	1/7	Very strong preference
8	1/8	Very strong to extreme preference
9	1/9	Extreme preference

TABLE 2 The AHP pairwise weight scale, adapted from (Saaty, 1980)

AHP also utilizes a consistency index which describes how self-consistent the pairwise comparisons are. A lower consistency index indicates that few pairwise comparisons are contradictory. For example, if the ranking process found that $A > B$, $B > C$, but $C > A$, the inconsistency index would increase. The accepted threshold for inconsistency in rankings is 0.1 (Linkov and Moberg, 2017).

In the AHP method, decision analysts either elicit the pairwise weights from experts or determine weights themselves. The goal is to determine appropriate criteria weights based on familiarity with the problem under consideration. However, the method accepts that these are not objective weights, and that different decision-makers or experts may rank criteria and alternatives according to their own biases (Linkov and Moberg, 2017). For oyster restoration in Washington, this attribute of AHP becomes a benefit. The variability in county and municipal permit requirements favors more flexible analytical frameworks which can be adapted to different scenarios.

I used the AHP package in R to perform the calculations for this analysis (Glur, 2018). Performing these calculations with R code ensures that calculation errors do not affect the outcome of the calculations, and also facilitates the calculation process. The AHP package reads

a YAML text file which defines the criteria, alternatives, and pairwise weights, and then performs the standard AHP calculation process with this information.

Methods

The decision I decided to analyze was, “which alternative permitting pathway should a county-level oyster restoration group use to reduce the regulatory burden on their project?” For this decision, I positioned myself as a decision analyst making a recommendation to county-level Olympia oyster restoration groups, who are the decision makers. Although the Puget Sound Restoration Fund has completed many projects at this scale, the type of decision-maker I kept in mind for this analysis would be the manager for an Olympia oyster restoration project, such as those planned by Marine Resource Councils (MRCs) in various coastal counties in Washington. These projects are often small-scale, and are performed by groups that do not only focus on shellfish restoration. The primary assumption in my analysis is that a county group has already identified a number of potential restoration sites which are physically and environmentally appropriate for Olympia oyster habitat. In the context of my analysis, this assumption narrows down the decision criteria to only regulatory considerations, though in reality there could be additional criteria which make a restoration site more or less suitable for oyster restoration projects. For my analysis, I approached the criteria selection and weighting process from the viewpoint of making suggestions for a broad range of county groups. I developed my criteria and alternatives from multiple project and governmental reports throughout coastal Washington. The list of documents in which I found information useful to determining criteria, alternatives, and relative weights are in Appendix B. I approached the selection of decision alternatives in the same fashion, identifying alternative permitting

pathways which can be broadly useful across different counties and municipalities. There are specific locations where local ordinances make some of the alternatives impossible to implement. However, most counties have potential permitting sites for which one or more of the alternative pathways apply.

Decision Criteria and Weights

All of the criteria I identified are characteristics of the all of the alternative permitting pathways I identified, which are discussed later in the report. Each criterion represents an aspect of the permitting process, though it may not be directly linked to a permit step. For example, time required to obtain all permits is a direct consequence of the permitting pathway chosen, but cost incorporates both the cost of the permits themselves as well as non-permit costs associated with choosing a particular permitting pathway. With this in mind, I identified the following criteria to incorporate into the decision analysis:

- **Cost:** Cost refers to the total cost of all required permits, as well as potential costs associated with acquiring an oyster restoration project permit such as staff salaries or operational fees. I assigned weights for this criterion based on both the listed costs for each permit (available on agency websites at the time of writing), and an assumption that project costs will be greater with a longer permitting timeline.
- **Time Required:** The estimated time required to obtain approval for all required permits. Estimates for individual permit application approval times vary from a few weeks to several months (Evrard, 2017). Some of the uncertainty in the overall permitting process can be attributed to the variability in approval times. At the time of writing, restoration groups are encouraged to expect permits to take a year, following the status quo

permitting pathway. Some permits can take longer if additional review or public comment is required (Lund and Hoberecht, 2016).

- **Certainty of Approval and Process:** Certainty captures both the certainty of all the steps in a permitting pathway from beginning to end, as well as the certainty that all of the permit applications or requests will be approved.
- **Flexibility in Site Selection:** Flexibility refers to the relative limitation of sites based on regulatory criteria. If a project manager does not take variable permit requirements into account when choosing a restoration site, the only criteria are the suitability and availability of a restoration site for Olympia oyster projects. If a project manager decides to only look at restoration sites with fewer permit requirements, the number of sites available for consideration decreases.
- **Efficiency:** Efficiency refers to the total number of permits required for an oyster restoration project. Refer to Table 1 for the list of permits which are required or optional depending on location-specific requirements.

	Cost	Time	Certainty	Siting	Efficiency
Cost	1	1/8	1/9	1/6	1/2
Time	8	1	1/2	3	3
Certainty	9	2	1	7	7
Siting	6	1/3	1/7	1	2
Efficiency	2	1/3	1/7	1/2	1

TABLE 2 Pairwise weights for decision criteria. The bolded line indicates the border between the pairwise weights and the reciprocal weights. The values along the middle diagonal for AHP pairwise comparison tables should always be 1.

Table 2 shows the pairwise weights I assigned to the criteria. I assigned these weights based on the information I gathered in the documents, articles, and reports listed in Appendix B. Though the reports do not always explicitly state that one criterion is preferable to another, I was able to determine from context and direct statements that some criteria were more important to restoration project managers. For example, Ulibarri et al. discusses common problems with environmental permitting processes, and states that costs associated with permitting become less manageable when projects are delayed due to the time required to obtain approval. The authors in that study state repeatedly that efficiency losses in permitting processes that arise due to uncertainty on the part of groups applying for environmental permits.

Because uncertainty can lead to poorer outcomes in permitting processes overall, and because of the common sentiment among both the restoration and commercial shellfish project managers that the shellfish permitting process is difficult to navigate without prior experience, the certainty criterion scored high relative to the other criteria. Overall, certainty appeared more important than other criteria due to its influence on environmental permitting outcomes. While it is not common for Olympia oyster restoration permits to be rejected, applications for restoration projects can sometimes become slowed or complicated by regulatory processes which are more commonly used for commercial shellfish permits.

Time required also ranked high relative to other criteria due to the association with cost. When permit approval time increases, costs related to staff and holding facilities for oyster larvae also increase. The most desirable permitting pathways will therefore have a high likelihood of timely approval.

Cost ranked lowest among all the criteria. This is not because the cost of a project is unimportant to restoration efforts, but because there is relatively low variability in permit costs unless conditional use permits are required. Permit costs can be included in preliminary budgets for restoration projects, and are typically expected for this type of project. Costs associated with the regulatory framework can be minimized by shortening the timeline for permit approval for a restoration project and avoiding areas with more permit requirements. Additionally, the fees for conditional use permits are sometimes waived by county governments for restoration projects if it is determined that the project meets certain criteria.

Decision Alternatives and Pairwise Comparisons

When examining the current permitting process for Olympia oyster restoration projects, it became clear that it is not possible to completely avoid permits. As mentioned earlier, this is not an issue in and of itself, as permitting regulations can help reduce environmental damage due to poorly planned projects. However, it is possible to avoid having to obtain some permits if restoration project managers are willing to limit themselves on what type of land they can choose for their projects. Avoiding areas which require more than the state and federally mandated permits can reduce the potential for a longer, more difficult permitting process. Another potential way to reduce permits would be to take advantage of the many existing shellfish aquaculture sites around Puget Sound. Commercial farms already have the full range of permits, and it is a simpler process to add a new species to an existing permit than going through the whole permitting process from the beginning. Finally, some permitting agencies are willing to waive permits typically required for shellfish projects in the case of shellfish restoration. However, this is not always the case, and counties' Shoreline Management

Programs have some variability in their definitions of restoration projects and the requirements for a permit waiver. The possibility of waiving permit requirements could be discussed in a preliminary meeting between the restoration project team and permitting agency representatives, a process which is already strongly recommended by the SIP team to facilitate the early stages of new oyster restoration projects (Lund and Hoberecht, 2016).

Based on this information, I developed four decision alternatives for permitting pathways for Olympia oyster restoration projects. Table 3 lists the decision alternatives and their descriptions. Alternative A is the “status quo” permitting pathway in that it does not include any direct actions for reducing the regulatory burden on Olympia oyster restoration projects. This alternative captures a wide range of permit situations, and the higher level of uncertainty and variability in the process causes this alternative to rank lower for time required, certainty, cost, and efficiency. However, some potential project sites which are highly favorable for availability and environmental suitability may also have lower regulatory requirements by chance due to the patchwork of permit requirements based on land ownership and county jurisdiction. Alternatives B, C, and D are preferable with regards to these criteria, and therefore all ranked higher than Alternative A, as they specifically target restoration sites or permitting strategies which reduce the regulatory burden for Olympia oyster restoration projects.

Alternative A	Status Quo: locate potential restoration sites based solely on availability and suitability for Olympia oyster settlement and growth; do not request permit exemptions
Alternative B	Preferentially locate restoration sites on land which is already permitted for shellfish aquaculture (commercial farms, shellfish gardens, existing restoration sites etc.); do not request permit exemptions
Alternative C	Preferentially locate restoration sites on tidelands with fewer permit requirements; do not request permit exemptions; exclude sites which require additional permits (eliminates counties and cities which require Conditional Use Permits)
Alternative D	Request permit exemptions from local and state agencies to eliminate need for full application process. Could be arranged during preliminary permit agency meetings

TABLE 3 Decision alternatives

Tables 4 - 8 show the pairwise comparisons for the decision alternatives. Alternatives B and C both aim to reduce the total number of permits required. Alternative B achieves this through collaboration with previously-permitted shellfish sites. This would require only the addition of a new species to the existing permit, or the modification of an existing restoration plan if the site in question is an environmental restoration site. Alternative B therefore ranks favorably for time required, efficiency, and certainty. In this case, the high certainty rank is based on the knowledge of a short, straightforward regulatory pathway rather than the certainty that an existing commercial shellfish permit-holder will agree to a collaboration allowing Olympia oyster restoration on his/her site. Alternative B ranks lower for flexibility of site selection due to the fact that project managers would need to limit their selection to areas which are already permitted for shellfish aquaculture.

Alternative C has similar strengths to Alternative B. Avoiding sites based in counties or municipalities which require conditional use permits would reduce the number of permits required for an oyster restoration project. Similarly, sites owned by the Department of Natural

Resources (DNR) would be removed from consideration due to the leasing requirement for these properties. Removing these steps simplifies the permitting pathway, leading to a higher level of certainty of getting through the regulatory process.

Alternative D centers on requesting permit exemptions from regulatory agencies. Completely removing the wait time for permit approval causes this alternative to rank high for time required, as well as efficiency. However, this is a less certain regulatory pathway, as there is more variability between permitting agencies with regard to willingness to exempt oyster restoration projects.

I used the AHP package for R to calculate the final decision preferences (Glur, 2018). The AHP package automatically converts the pairwise weights into numerical values which it then uses to calculate the priority vectors of the criteria matrix. The vectors of this matrix become the weights for each criterion. The program applies the same method to the alternatives matrices. After both vector calculations, the program checks for consistency in the pairwise weights. This value is displayed as an inconsistency index, which must be below 0.1 for model validity. Finally, the program sums all the weighted priorities for each alternative. The alternative with the highest sum is the most favorable pathway for county-level organizations to use.

Cost

	A	B	C	D
A	1	1/5	1/3	1/5
B	5	1	3	1/3
C	3	1/3	1	1/3
D	5	3	3	1

Time

	A	B	C	D
A	1	1/7	1/3	1/9
B	7	1	7	1/3
C	3	1/7	1	1/7
D	9	3	7	1

Certainty

	A	B	C	D
A	1	1/8	1/4	2
B	8	1	3	5
C	4	1/3	1	3
D	1/2	1/5	1/3	1

Siting

	A	B	C	D
A	1	8	7	1
B	1/8	1	1/4	1/8
C	1/7	4	1	1/7
D	1	8	7	1

Efficiency

	A	B	C	D
A	1	1/7	1/5	1/8
B	7	1	3	1/3
C	5	1/3	1	1/5
D	8	3	5	1

Tables 4 – 8 Pairwise weights for the decision alternatives A, B, C, and D with respect to each decision criterion. The values above the diagonal are the pairwise weights, and the values below are the reciprocal weights.

Results and Discussion

	Weight	Alternative B	Alternative D	Alternative C	Alternative A	Inconsistency
Permit Pathway	100.0%	41.3%	28.9%	18.6%	11.2%	4.5%
Certainty	51.4%	29.6%	3.4%	14.0%	4.4%	7.1%
Time	26.2%	8.4%	14.6%	2.1%	1.1%	9.6%
Siting	12.0%	0.5%	5.2%	1.1%	5.2%	7.6%
Efficiency	6.9%	1.9%	3.9%	0.9%	0.3%	7.6%
Cost	3.4%	1.0%	1.7%	0.5%	0.2%	7.5%

TABLE 9 The results of the AHP analysis performed in R. Darker shading indicates higher scores or weights, while lighter shading indicates lower scores or weights. Alternative B ranked highest among the decision alternatives, and Alternative A ranked the lowest. Certainty and time required were the most important criteria.

Table 9 displays the weighted criteria, individual alternative weights for each criterion, and the overall alternative ranks.

Certainty received the highest weight among the criteria with a score of 0.514. This means that the certainty criterion receives approximately 51.4% of the overall importance of the criteria. Time required for approval also received a high weight of 0.262 meaning that it receives approximately 26.2% of the overall importance of the criteria. The remaining criteria received significantly lower weights, making their contributions to the overall criteria importance less influential.

Alternative B, wherein Olympia oyster restoration projects would collaborate with already-permitted shellfish sites, ranked the highest out of the four alternatives with a score of 0.413. Alternative A, which was the status quo alternative, ranked lowest with a score of 0.112. Alternative D ranked second with a score of 0.296 due to its high score for time required. Alternative C ranked third, though it did score second for certainty.

	Weight	Alternative D	Alternative B	Alternative C	Alternative A	Inconsistency
Permit Pathway	100.0%	42.5%	29.9%	14.3%	13.4%	0.0%
Cost	20.0%	10.1%	5.8%	2.9%	1.3%	7.5%
Certainty	20.0%	1.3%	11.5%	5.4%	1.7%	7.1%
Siting	20.0%	8.7%	0.8%	1.8%	8.7%	7.6%
Efficiency	20.0%	11.2%	5.4%	2.6%	0.8%	7.6%
Time	20.0%	11.2%	6.4%	1.6%	0.8%	9.6%

TABLE 10 The results of the sensitivity analysis performed in R. When the criteria are weighted equally, Alternative D (requesting permit exemptions) is the most preferable alternative. Alternative B ranks second, and Alternatives A and C do not change rank.

I also performed a sensitivity analysis to determine how the model reacts to changes in criteria weights. Because Certainty and Time made up the majority of the total criteria importance, I focused my analysis on those two factors. Table 10 shows the results of the AHP analysis when all criteria are weighted equally. In this case, requesting permit exemptions is the best alternative, followed by collaborating with previously-permitted sites. This is not an unexpected result, as Alternative D scores better in nearly all criteria categories except for certainty.

	Weight	Alternative D	Alternative B	Alternative C	Alternative A	Inconsistency
Permit Pathway	100.0%	36.5%	34.5%	16.4%	12.6%	0.0%
Certainty	33.3%	2.2%	19.2%	9.1%	2.9%	7.1%
Cost	16.7%	8.4%	4.8%	2.4%	1.1%	7.5%
Siting	16.7%	7.2%	0.7%	1.5%	7.2%	7.6%
Efficiency	16.7%	9.3%	4.5%	2.1%	0.7%	7.6%
Time	16.7%	9.3%	5.3%	1.3%	0.7%	9.6%

	Weight	Alternative B	Alternative D	Alternative C	Alternative A	Inconsistency
Permit Pathway	100.0%	37.8%	32.2%	18.0%	12.0%	0.0%
Certainty	42.9%	24.7%	2.9%	11.7%	3.7%	7.1%
Cost	14.3%	4.1%	7.2%	2.0%	0.9%	7.5%
Siting	14.3%	0.6%	6.2%	1.3%	6.2%	7.6%
Efficiency	14.3%	3.9%	8.0%	1.8%	0.6%	7.6%
Time	14.3%	4.6%	8.0%	1.2%	0.6%	9.6%

Tables 11 and 12 The break-even point for Alternatives B and D with regards to the Certainty criterion. This portion of the analysis supports the finding that requesting permit exemptions is the preferable option when certainty is not given as much weight in the model.

Because of the nature of the AHP scale, it was not possible to find the exact break-even weighting point for Alternatives B and D with regard to the Certainty criterion. However, Tables 11 and 12 show that the break-even point for these two alternatives is found when Certainty is given between 33.3% and 42.9% of the overall importance of the criteria, assuming all other criteria are weighted equally. Even though this doesn't show the exact break-even point, the two tables show that the ranking of alternatives does not fluctuate significantly with small changes to the model.

The two results of the sensitivity analysis indicate that when restoration groups are not as concerned about certainty in the permitting process, the best option is to request permit exemptions. Because Alternatives B and D switch rank in a logical manner, while A and C remain unchanged in rank, this analysis supports the strength and reliability of this model.

Preferentially targeting already-permitted sites such as commercial shellfish farms or shellfish gardens has benefits and limitations for Olympia oyster restoration groups. The obvious strength of this alternative is the simplicity of the permitting pathway relative to other strategies, which also decreases the amount of time required for permit approval. Making changes to existing permits is an easier process than beginning a new JARPA, and the current permit-holder would likely have experience to assist the restoration project managers in navigating the permitting process. However, the number of potential restoration sites would decrease substantially from the initial list of available and environmentally suitable areas. The extent of this limitation depends greatly on the region under consideration, because some counties have many more commercial aquaculture and shellfish garden sites than others. Shellfish aquaculture in Washington is concentrated in south Puget Sound, Grays Harbor and Willapa Bay Washington State Department of Health," 2018). Projects based in less prolific growing areas may be overly limited by this permitting pathway. Another limitation on the number of sites available using this permitting alternative is the fact that Olympia oyster habitat differs from the ideal habitat for Pacific oysters, which are the most commonly farmed oyster species in Washington. The initial site criterion of ecological suitability could eliminate many potential collaborator sites due to poor habitat conditions, thereby further limiting site selection.

Alternative D, in which oyster restoration managers ask for permit exemptions, also ranked high among the decision alternatives due to its high scores for time required, flexibility of site selection, and efficiency. Alternative D was the most preferable pathway with regards to cost, though the low weight of the cost criterion makes this a less important quality in the decision analysis. The only criterion in which this alternative did not receive a high score was certainty. As mentioned previously, the ability to receive permit exemptions varies depending on regulatory offices, local policies, and project details. Although this alternative would be the best case scenario for any restoration project, project managers would not be certain their project would be granted any permit exemptions. The low certainty and high variability reduces this alternative's rank significantly.

Alternative A ranked lowest among the criteria, which was the expected result. The status quo alternative captures a wide range of permitting scenarios, but the possibility of encountering many situations where permits may be extensive, complex, and expensive lowers the rank of this alternative for all criteria. The only criterion in which Alternative A did not rank last was flexibility in siting, due to the fact that no suitable restoration sites are eliminated for regulatory reasons.

As mentioned previously, location-specific regulations and policies are very important to determining which permitting pathways are available to a particular Olympia oyster restoration project. For example, permitting costs associated with conditional use permits may be waived for restoration projects automatically (as is the case on Bainbridge Island) or they may be included in the permitting costs for a project (City of Bainbridge Island Shoreline Master Program, 2014, sec. 5.2.4). Some county SMPs do not provide complete guidance on permit

requirements or exemptions, and in such cases restoration groups must contact local managers for information. The SIP team and many county and local agencies recommend arranging informational meetings with any regulatory agencies which will be involved in a restoration project (Lund and Hoberecht, 2016). This preliminary action reduces uncertainty in the process and provides guidance on permitting options available for individual restoration projects. It can also give permitting agencies early notice that a new Olympia oyster restoration project application is beginning, and could potentially prevent the application from running into regulatory barriers associated with commercial shellfish aquaculture permits.

Even though the feasibility of the alternatives in this analysis varies based on each project's location-specific requirements, the method by which the alternatives are ranked can be useful to managers when making decisions about individual oyster restoration projects. Given a set of local permitting pathway alternatives, managers can identify their own project-specific criteria and weights. The AHP method of breaking down a complex problem into more manageable pairwise comparisons is highly flexible, and can easily be applied to different regulatory scenarios, and Olympia oyster restoration groups could use this model to make decisions, resetting weights and changing alternatives to meet their location-specific needs. Furthermore, the AHP method's 1-9 scale is more easily explained to stakeholders and experts who may be involved in the determining criteria and alternatives priorities. The adaptability of the AHP model combined with the wide recognition of its use as a rigorous decision analysis method make it a good option for oyster restoration managers who may want to add a level of certainty and credibility to their decision-making processes.

Conclusion

Restoration groups have found strategies to better navigate the regulatory pathways surrounding application for oyster restoration permits. Although there is no strategy which completely avoids the permitting process, there are options which reduce the number of steps in the regulatory process. Finding already-permitted aquatic land and requesting permit exemptions proved to be good alternatives to the status quo process, and combining these alternatives could be an effective strategy to reduce the regulatory burden on Olympia oyster restoration projects. Making decisions early in the planning process to reduce regulatory barriers before they emerge could help smaller restoration projects expedite the oyster restoration process.

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Appendix B: Documents Used to Determine Decision Alternatives and Criteria Weights for AHP Analysis

Document	Author or Institution	Date
Shoreline Master Programs (SMP)		
Skagit County Draft SMP	Skagit County, WA	2016 (Draft)
Jefferson County SMP	Jefferson County, WA	2014
City of Bainbridge Island SMP	Bainbridge Island, WA	2014
Whatcom County Shoreline Management Program	Whatcom County, WA	2008
Olympia Oyster Restoration and Permitting Reports		
Restoration of the Native Oyster in Fidalgo Bay Year Ten Report	Gabrian-Voorhees et al.	2013
Restoration of the Native Oyster, <i>Ostrea lurida</i> , In Fidalgo Bay, Padilla Bay, and Cypress Island Year Fourteen Report	Dinnel	2016
Olympia Oyster Field Guide	Peabody and Davis	2013
A Guide to Olympia Oyster Restoration and Conservation	Wasson et al.	2015
Shellfish Interagency Permitting Team Phase I Report	Lund and Hoberecht	2016
Inventory of Shellfish Restoration Permitting and Programs in the Coastal States	Mississippi-Alabama Sea Grant	2014
Other Sources		
A Framework for Building Efficient Environmental Permitting Processes	Ulibarri et al.	2017
Washington Shellfish Aquaculture: Assessment of the Current Regulatory Frameworks	Evrard	2017
Farming Coastal Waters: Applied Research Supports Oyster Growers	North Carolina Sea Grant	2018