NATURAL RESOURCES

Aquatic Resources Program
Endangered Species Act
Compliance
Project

# Effectiveness Monitoring Design: Suggested Approaches and Considerations

*November 2007*

WASHINGTON STATE DEPARTMENT OF
**Natural Resources**
**Doug Sutherland** - Commissioner of Public Lands

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# 1. Introduction

This Effectiveness Monitoring Design report is one of several documents developed to assist the Washington State Department of Natural Resources (Washington DNR) Aquatic Resources Program with its development of a Habitat Conservation Plan (HCP) for state-owned aquatic lands. The objective of the report is to develop and describe a process that would enable Washington DNR to draw conclusions regarding whether or not species and habitats would realize benefits from widespread implementation of proposed conservation measures: that is, to determine whether measures are "effective."

Habitat Conservation Plans generally include three types of monitoring – implementation, effectiveness and validation. Based on Noss and Cooperrider (1994), Washington DNR defines the three types of monitoring as follows:

- Implementation - "…the process of determining if a planned activity was accomplished."
- Effectiveness - "…to determine if some human activity is having the desired effect."
- Validation - "…scientific testing of the validity of the models and assumptions upon which a monitoring program is based."

Conservation measures specifying *activities*, such as ongoing submerged vegetation monitoring, or *tasks*, such as developing and maintaining a spill response kit, clearly fall within the realm of implementation monitoring. In contrast, measures specifying a *desired effect*, such as artificial lighting not illuminating surrounding waters, fall within the domain of effectiveness monitoring. In the latter case, if the objective of the measure was to reduce artificial ambient light to levels that do not preclude nighttime migration of salmonids, effectiveness monitoring might show that salmon do not respond to reduction of artificial light in estuarine or nearshore environments, but do exhibit a significant response in riverine ecosystems. Validation monitoring could then be used to examine whether the absence of a response was due to insufficient light reduction, behavioral differences—for example, that larger fish in estuaries migrate during daylight hours—or to shortcomings in the conceptual understanding of the relationship between salmon and artificial light.

It was not possible within the scope of this contract to design specific programs to test the effectiveness of each of the large number of proposed conservation measures. Instead, a limited set of measures was examined in detail, and a pilot effectiveness monitoring program for one conservation measure was implemented with a limited field study. This process enabled documentation of the approaches and universal considerations that could be repeated in a stepwise fashion for other conservation measures. The following concepts were identified as guiding principles in the process:

- Delineate a process that Washington DNR can easily repeat.
- Efficiently use limited financial resources and examine the implications of different levels of resource allocation.
- Design monitoring programs that are robust and easily adaptable across saltwater, lacustrine and riverine ecosystems.
- Address the uncertainties surrounding a measure.
- Inform decisions regarding implementation of conservation measures.

The effectiveness monitoring design process described in the following chapters provides a framework to determine whether the implementation of a conservation measure ("human activity") has the desired effect (Noss and Cooperrider 1994). This program is both robust and adaptable, and provides Washington DNR the ability to adjust to unforeseen circumstances that are associated with almost any field program. The process consists of a series of stepwise procedures for identifying elements to monitor (Chapter 2), developing the monitoring program design (Chapter 3), and implementing the program (Chapter 4).

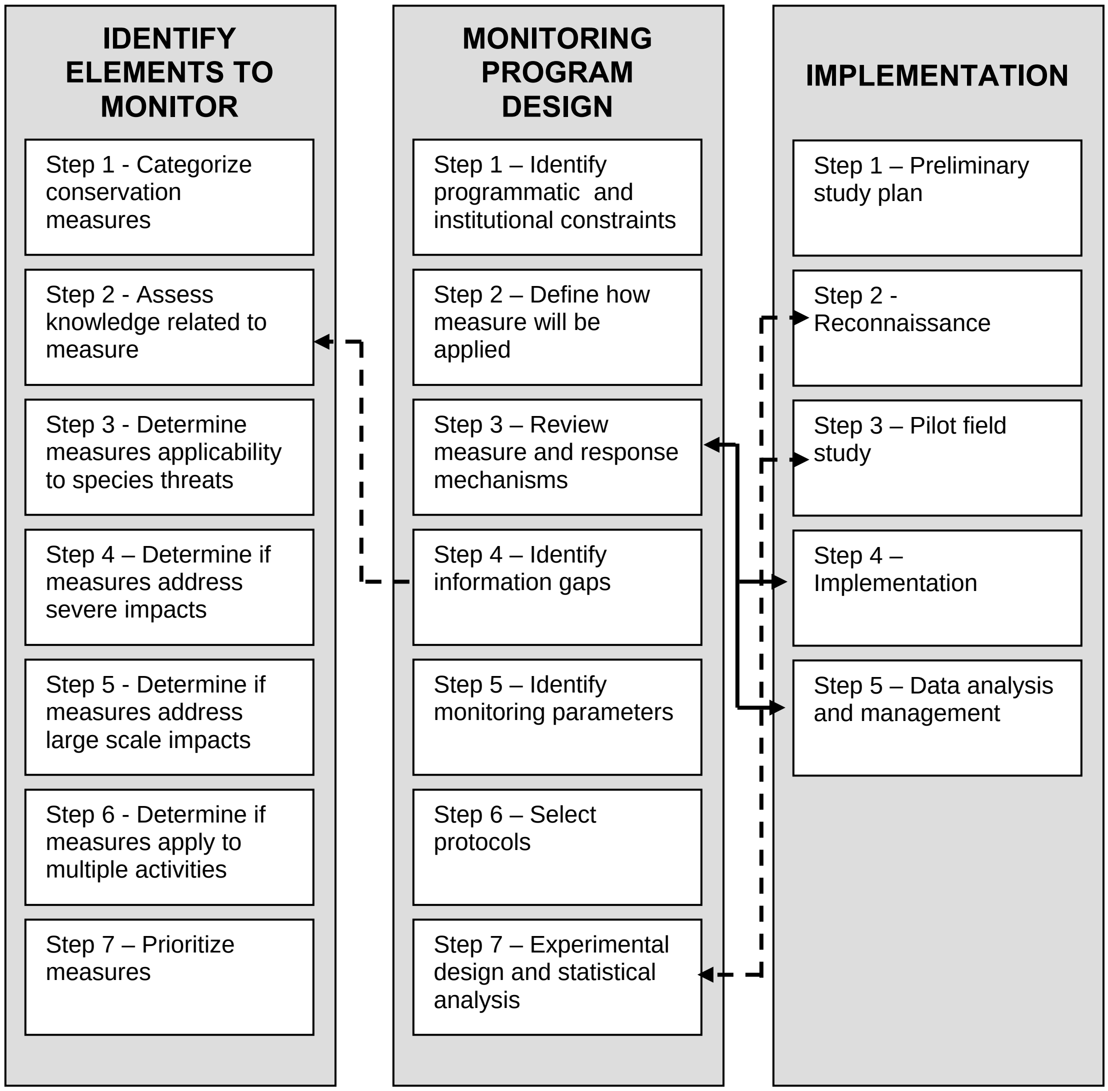
The prioritization protocols described in Chapter 2 were developed with the intent of maximizing finite monitoring resources by focusing effort on the examination of conservation measures with the greatest potential to provide benefits to species, habitats, and ecosystems. The design process is powerful in part because of the use of conceptual models that guide hypothesis formation. Another key feature is the use of multiple indicators, such as light transmission, salmon, and submerged aquatic vegetation, rather than a single parameter.

The before, after, control, impact (BACI) experimental design described in Chapter 3 is rigorous in its use of controls and replicates, and thus avoids the potential pitfalls associated with observational studies or unreplicated comparisons of treated and reference sites. The recommended experimental design is also scalable and can be adjusted to accommodate different levels of resource allocation.

The steps presented in Chapter 4 outline the critical activities necessary to implement a successful effectiveness monitoring design process. They can be applied to any field study designed to quantify the effectiveness of a conservation measure, regardless of habitat or species. The steps allow clear definition of a study's goals or objectives by obtaining information necessary to 1) develop the conceptual understanding of the issue, 2) establish the critical parameters to monitor, and 3) determine the most effective sampling design. Guidelines are presented for designating the initiation- and completion-timing of the study, and for acting on the results of the study.

Because the effectiveness monitoring design process centered on specific conservation measures, it was possible to identify commonalities in the monitoring approach that could be generalized to a stepwise process. Both the pilot field study (Appendix A) and the light transmission work plan (Appendix B) provided valuable input to the implementation section. Finally, this design process provides a basic scientific foundation needed to inform decisions regarding widespread implementation of specific conservation measures. It allows evaluation of a measure's effectiveness for a particular class of activities and for particular ecosystems. Rigor and certainty will be especially important as Washington DNR moves forward with implementation of the HCP, because constituents may be reluctant to adopt costly or poorly understood modifications.

**Figure 1-1. Effectiveness monitoring program design process overview.**



# 2. Identifying Elements to Monitor

The objective of this chapter is to delineate a process for prioritizing selection of conservation measures for inclusion in an effectiveness monitoring plan. Measures evaluated were chosen from a list of 56 conservation measures for three activity categories provided by Washington DNR (Appendix C). The steps described in the following pages document the process used to determine the conservation measures that are most important to examine and the order in which to study them. For each step, the objective is defined, the rationale for evaluation criteria is provided, and examples of the application of evaluation criteria are presented.

Because a single conservation measure could be associated with multiple activity types, a prioritization process will allow Washington DNR to identify the activities that merit the earliest examination. A prioritization process also reduces the overall list and focuses the monitoring plan by:

- Eliminating conservation measures that are more appropriately monitored as part of an “implementation” monitoring framework.
- Focusing monitoring resources (financial, capital, human or other) on conservation measures that have the greatest potential to provide benefits for species, habitats, and ecosystems.
- Using monitoring resources to address information gaps rather than areas where science has already demonstrated efficacy.
- Creating a process that will enable Washington DNR to respond to changes in either the “state of knowledge” or programmatic objectives.

The steps in the prioritization process are as follows:

- Step 1: Categorize conservation measures with respect to type of monitoring plan.
- Step 2: Determine whether conservation measures directly address primary species threat.
- Step 3: Determine whether conservation measures address impacts that are severe.
- Step 4: Determine whether conservation measures address impacts that are large in area.

- Step 5: Assess the state of knowledge regarding conservation measures.
- Step 6: Determine whether conservation measures can be applied across several activity groups.
- Step 7: Prioritize conservation measures on basis of cumulative score.

Elements for the prioritization protocol were drawn from the monitoring literature in general as well as from some key publications (Noss and Cooperrider 1994, US Forest Service 1999, Block et al. 2001, Fresh et al. 2004). Steps 2 through 6 describe a process for evaluating and scoring individual conservation measures according to their merits. Step 7 describes a process for ranking individual measures based on the cumulative scores from the previous steps. Measures receiving the highest scores also receive the highest priority for additional examination. Specific decision points within each step rely heavily on information and data developed by and for Washington DNR in an earlier phase of the HCP development. The Potential Effects and Expected Outcomes Technical Paper (Washington DNR 2007) provided the conceptual framework for understanding the relationship between the impacts of authorized activities, species, and habitats. For the purposes of this document, it was assumed that the reader would be familiar with the analytical methods used in the prior analyses. Readers with less familiarity should refer to the following documents for background information:

- Covered Species Technical Paper (Washington DNR 2007)
- Covered Habitat Paper Technical Paper (Washington DNR 2005)
- Covered Activities Technical Paper (Washington DNR 2005a)
- Potential Effects and Expected Outcome Technical Paper (Washington DNR 2007a)

For the convenience of the reader, Appendix D presents a list of proposed Covered Species (Table D-1), Covered Activities (Table D-2) and Covered Habitats (Table D-3).

## Step 1: Categorize conservation measures with respect to type of monitoring plan

The objective of the first step in the prioritization process is to identify conservation measures that potentially fall within the domain of effectiveness monitoring versus those that are more appropriately part of implementation monitoring. Conservation measures requiring validation monitoring can be identified in the course of conceptual model development (Chapter 3) or at the completion of the initial round of effectiveness monitoring. Although the process of distinguishing implementation from effectiveness measures is somewhat subjective, the following criteria were used in the present study:

- Is the currency of the monitoring programmatic or ecological?
- Is the wording of the conservation measure sufficiently specific to be testable?

Only measures identified in Appendix C to be appropriate for an effectiveness monitoring program were carried forward in the prioritization process.

## Step 2: Assess the state of knowledge regarding conservation measures

### OBJECTIVE

The objective of Step 2 is to conduct a preliminary assessment of the state of science with respect to individual conservation measures. The intent of this step is to give greater weight to the examination of conservation measures for which the expected response is uncertain versus those for which the expected response is well understood. By emphasizing uncertainty over certainty, we focus limited monitoring resources on the most relevant questions. If a substantial body of evidence exists to suggest that a particular conservation measure is effective, or if the body of evidence is sufficiently broad to make inferences about expected responses, then there may be no compelling reason for Washington DNR to allocate resources to additional study. This step in the prioritization framework was also designed to address the absence of interaction between authorized uses and certain groups of species. For example, amphibians are unlikely to exhibit a response to implementation of conservation measures associated with nearshore saltwater aquaculture.

### PRIORITIZATION PROTOCOL

Table 2-1 illustrates the criteria that were used to evaluate each of the individual conservation measures with respect to the current understanding of effectiveness. The Potential Effects Analysis and Expected Outcomes Technical Paper (Washington DNR 2006) was one of the primary information sources used in making the determinations described below; professional judgment was also used. If a conservation measure was determined to effectively address a potential stressor for a species group, the measure received a score of zero. If there was no interaction between a species group and the stressor addressed by the measure, it received a score of zero. If the body of knowledge suggested that the efficacy of a conservation measure was uncertain, the measure received a score of one. It was assumed for the purposes of this analysis that Washington DNR would not knowingly select a conservation measure for inclusion in the HCP that had been demonstrated ineffective. Table 2-2 provides an example of the Step 2 scoring protocols as they relate to conservation measures currently under consideration. None of the 56 conservation measures evaluated received low scores on the basis that the body of evidence was sufficient to preclude the need for additional monitoring. However, it is not clear whether this is a result of 1) absence of documented causal relationships, 2) the superficial nature of the examination at this point in the process, or 3) the suite of measures available for review. More rigorous review of the conceptual relationship between the conservation measure and the expected response is a central component of monitoring design (Chapter 3). The values in Table 2-2 were then used in the final ranking of conservation measures, which is described in greater detail in Step 7.

**Table 2-1. Evaluation criteria for assessment of the state of knowledge regarding individual conservation measures.**

| Current State of Knowledge | Score |
|---|---|
| Efficacy of measure is uncertain | 1 |
| Body of evidence indicates efficacy of measure is certain. | 0 |
| Absence of interaction leads to conclusion that measure is ineffective for species-activity combination | 0 |

**Table 2-2. Example of the prioritization protocol with respect to the state of knowledge for a conservation measure.**

| Conservation Measure | Amphibians & Reptile | Birds | Fish | Marine Mammal |
|---|---|---|---|---|
| Site log storage areas and transfer facilities in areas with good currents and tidal exchanges. | 1 [a] | 1 [a] | 1 [a] | 0 [b] |
| Incorporate measures that increase the ambient light transmission under piers and docks. These measures include, but are not limited to, maximizing the height of the structure and minimizing the width of the structure to decrease shade footprint (replacement maintenance); grated decking material; using solar tubes to direct light under the structure and glass blocks to direct sunlight under the structure; illuminating the under structure area with metal halide lamps and use of reflective paint or materials (e.g., concrete or steel instead of materials such as wood that absorb light) on the underside of the dock to reflect ambient light. | 1 [a] | 1 [a] | 1 [a] | 1 [a] |
| Ensure that net pen structures have webbing of appropriate size to prevent entanglement by Covered Species and their prey. | 0 [b] | 0 [ab] | 1 [a] | 0 [b] |

a - Measure addresses an identified threat to species group.
b - Absence of interaction.

# Step 3: Determine whether conservation measures directly address primary species threats

## OBJECTIVE

Step 3 was designed to identify the conservation measures that directly address primary threats for the proposed Covered Species. For the purposes of this document, threats can be classified in one of the following ways:

- Destruction, modification, or curtailment of habitat or range;
- Overuse for commercial, recreational, scientific, or educational purposes;
- Disease or predation;
- Adequacy of existing regulatory mechanisms; and
- Other factors affecting continued existence.

The rationale for this part of the process is that one of the greatest opportunities to recover endangered, threatened, or imperiled species is to avoid or minimize factors that have been identified as primary threats to their continued existence.

## BACKGROUND

Table 2-3 identifies the proposed Covered Species and provides a summary list of threats that was originally presented in the Covered Species Technical Paper (Washington DNR 2007). Although not all of the species threats (e.g., increase in ultraviolet B radiation) fall under Washington DNR's control, the intent of this part of the prioritization protocol is to emphasize the cases in which Washington DNR proposed to apply a conservation measure to address a primary species threat.

**Table 2-3. Proposed Covered Species and primary threats (Washington DNR 2007).**

| Species Group | Species | Primary Threats |
|---|---|---|
| Amphibians & Reptile | Columbia spotted frog | ▪ Changes in hydrology and water quality<br>▪ Bullfrog and non-native fish predation<br>▪ Beaver removal<br>▪ Increase in ultraviolet B radiation |
| | Northern leopard frog | ▪ Small population size<br>▪ Habitat modification<br>▪ Bullfrog and non-native fish predation<br>▪ Exposure to fertilizers and pesticides<br>▪ Vehicle mortality<br>▪ Increase in ultraviolet B radiation |

| Species Group | Species | Primary Threats |
|---|---|---|
| | Western toad | ▪ Habitat fragmentation/isolation<br>▪ Raven predation<br>▪ Increase in ultraviolet B radiation |
| | Western pond turtle | ▪ Habitat alteration/degradation<br>▪ Loss of nests to human activities<br>▪ Removal from the wild by humans<br>▪ Loss of hatchlings to bullfrogs and other predators<br>▪ Disease |
| Birds | Bald eagle | ▪ Human disturbance<br>▪ Shoreline modification<br>▪ Toxic bioaccumulative pollutants<br>▪ Reduced prey abundance |
| | Black tern | ▪ Wetland loss<br>▪ Invasive plants alter habitat structure<br>▪ Nest predation<br>▪ Human disturbance |
| | California brown pelican | ▪ Toxic bioaccumulative pollutants<br>▪ Marine circulation and prey abundance |
| | Common loon | ▪ Shoreline modification<br>▪ Lake or reservoir level fluctuations<br>▪ Human disturbance resulting in nest predation by opportunistic predators<br>▪ Entanglement/entrapment in gill nets<br>▪ Toxic bioaccumulative pollutants |
| | Harlequin duck | ▪ Stream and shoreline habitat degradation<br>▪ Human disturbance in nesting, molting, and wintering habitat<br>▪ Nest predation<br>▪ Entanglement/entrapment in gill nets<br>▪ Toxic bioaccumulative pollutants |
| | Marbled murrelet | ▪ Harvest of old-growth forests<br>▪ Nest predation<br>▪ Entanglement/entrapment in gill nets<br>▪ Oil spill mortality<br>▪ Toxic bioaccumulative pollutants<br>▪ Marine circulation and prey abundance |
| | Western snowy plover | ▪ Loss of habitat to commercial and residential development<br>▪ Human disturbance<br>▪ Invasive exotic beach grasses<br>▪ Dune stabilization |
| Fish | Bull trout/Dolly Varden | ▪ Increased water temperature<br>▪ Fragmentation of migratory corridors<br>▪ Hybridization with brook trout<br>▪ Small population size |

| Species Group | Species | Primary Threats |
|---|---|---|
| | Chinook salmon | ▪ Habitat degradation and loss<br>▪ Mortality from hydroelectric dams and water diversions<br>▪ Increased siltation and embryo mortality<br>▪ Overharvest<br>▪ Fragmentation of migratory corridors<br>▪ Competition of hatchery stocks |
| | Chum salmon | ▪ Habitat degradation and loss<br>▪ Increased siltation and embryo mortality<br>▪ Overharvest<br>▪ Genetic dilution from hatchery stocks<br>▪ Water quality degradation |
| | Coastal cutthroat trout | ▪ Habitat destruction and degradation<br>▪ Sport fishing over harvest<br>▪ Fragmentation of migratory corridors |
| | Coho salmon | ▪ Habitat destruction and degradation<br>▪ Mortality from hydroelectric dams and water diversions<br>▪ Overharvest<br>▪ Fragmentation of migratory corridors |
| | Pink salmon | ▪ Habitat degradation and loss<br>▪ Fragmentation of migratory corridors<br>▪ Increased siltation and embryo mortality<br>▪ Sea lice from net pen aquaculture |
| | Sockeye/Kokanee salmon | ▪ Habitat degradation and loss<br>▪ Fragmentation of migratory corridors<br>▪ Increased siltation and embryo mortality<br>▪ Overharvest<br>▪ Water quality degradation |
| | Steelhead/rainbow trout | ▪ Habitat degradation and loss<br>▪ Fragmentation of migratory corridors<br>▪ Increased siltation and embryo mortality<br>▪ Overharvest<br>▪ Water quality degradation |
| | Green sturgeon | ▪ Loss and/or destruction of spawning habitat<br>▪ Entrainment of juveniles by water diversions<br>▪ Bycatch<br>▪ Lethal temperatures for larvae<br>▪ Bioaccumulation of toxics |
| | White sturgeon | ▪ Loss of spawning and rearing habitat from dam construction<br>▪ Channel modification<br>▪ Recruitment failure<br>▪ Overharvest<br>▪ Lethal water temperatures for eggs and larvae<br>▪ Decreased dissolved oxygen from anthropogenic eutrophication |

| Species Group | Species | Primary Threats |
|---|---|---|
| Marine Mammal | Southern resident killer whale | ▪ Oil spills<br>▪ Whale watching<br>▪ Prey abundance<br>▪ Small population size<br>▪ Bioaccumulation of toxins<br>▪ Noise pollution |

## PRIORITIZATION PROTOCOL

Table 2-4 provides an example of conservation measure scoring with respect to species threats. If a measure was determined to directly address a threat (Table 2-3) to a species group, the conservation measure received a score of two, whereas if the measure indirectly addressed a threat, it received a score of one. If the conservation measure did not address a threat to a species group, it received a score of zero. For example, moving log storage areas and transfer facilities to areas with good currents and tidal exchanges would presumably address direct threats for salmonids, such as water quality and habitat degradation. Measures to increase light transmission through overwater structures indirectly address threats to birds by addressing factors that limit the growth of submerged aquatic vegetation. The values in Table 2-4 were then used in the final ranking of conservation measures, which is described in greater detail in Step 7.

**Table 2-4. Example of the prioritization protocol with respect to species threats.**

| Conservation Measure | Amphibians & Reptile | Birds | Fish | Marine Mammal |
|---|---|---|---|---|
| Site log storage areas and transfer facilities in areas with good currents and tidal exchanges. | 1 | 2 | 2 | 0 |
| Incorporate measures that increase the ambient light transmission under piers and docks. These measures include, but are not limited to, maximizing the height of the structure and minimizing the width of the structure to decrease shade footprint (replacement maintenance); grated decking material; using solar tubes to direct light under the structure and glass blocks to direct sunlight under the structure; illuminating the under structure area with metal halide lamps and use of reflective paint or materials (e.g., concrete or steel instead of materials such as wood that absorb light) on the underside of the dock to reflect ambient light. | 0 | 1 | 2 | 0 |

| Conservation Measure | Amphibians & Reptile | Birds | Fish | Marine Mammal |
|---|---|---|---|---|
| Ensure that net pen structures have webbing of appropriate size to prevent entanglement by Covered Species and their prey. | 0 | 0 | 0 | 0 |

## Step 4: Determine whether conservation measures address severe impacts

### OBJECTIVE

Step of 4 of this analysis is intended to examine the proposed conservation measures to ascertain whether they addressed impacts that were severe in nature. The assumption implicit within this part of the prioritization protocol is that addressing severe impacts provides 1) the greatest opportunity to realize benefits for species, habitats, and ecosystems, and 2) the greatest likelihood of exhibiting a measurable response. Assessment of “severity” was based on information from the Potential Effects and Expected Outcomes Technical Paper (Washington DNR 2006) and on expert opinion.

### PRIORITIZATION PROTOCOL

If a conservation measure was determined to directly address a severe impact from an activity group, it received a score of two, whereas if the measure indirectly addressed a severe impact, it received a score of one. If the conservation measure did not address a severe impact from an activity group, it received a score of zero. The values in Table 2-5 were then used in the final ranking of conservation measures, which is described in greater detail in Step 7.

**Table 2-5. Example of the prioritization protocol with respect to the severity of impacts.**

| Conservation Measure | Amphibians & Reptile | Birds | Fish | Marine Mammal |
|---|---|---|---|---|
| Site log storage areas and transfer facilities in areas with good currents and tidal exchanges. | 0 | 2 | 2 | 0 |
| Incorporate measures that increase the ambient light transmission under piers and docks. These measures include, but are not limited to, maximizing the height of the structure and minimizing the width of the structure to decrease shade footprint (replacement maintenance); grated decking material; using solar tubes to direct light under the structure and glass blocks to direct sunlight under the structure; illuminating the under | 1 | 1 | 1 | 1 |

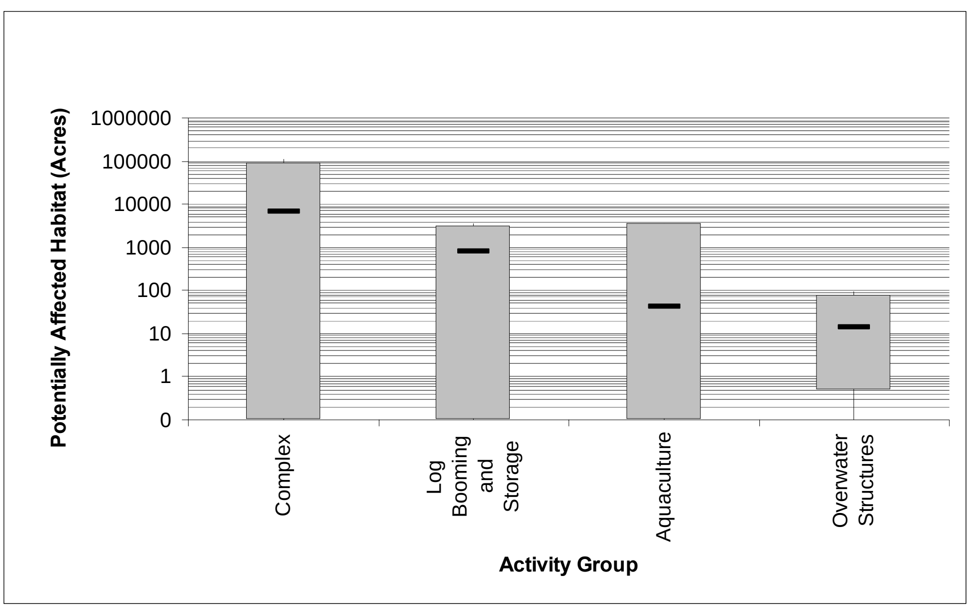
| Conservation Measure | Amphibians & Reptile | Birds | Fish | Marine Mammal |
|---|---|---|---|---|
| structure area with metal halide lamps and use of reflective paint or materials (e.g., concrete or steel instead of materials such as wood that absorb light) on the underside of the dock to reflect ambient light. | | | | |
| Ensure that net pen structures have webbing of appropriate size to prevent entanglement by Covered Species and their prey. | 0 | 0 | 2 | 0 |

# Step 5: Determine whether conservation measures address impacts that are large in area

## OBJECTIVE

The objective of this analysis was to examine the potentially affected habitat calculations to ascertain the relative impact of the proposed Covered Activities on proposed Covered Species. Information used in the analysis was generated as part of the Potential Effects Analysis and Expected Outcomes Technical Paper (Washington DNR 2007a). Figure 2-1 graphically illustrates the range of potentially affected habitat values attributed to a given activity group for all of the possible species-lifestage combinations.

**Figure 2-1. Range of potentially affected habitat areas for each species-lifestage combination (the solid line indicates the median of potentially affected habitat areas, the shaded boxes illustrate values between the 25th and 75th percentiles and the whiskers illustrate the 10th and 90th percentiles).**



For example, affected acreage for the Complex activity group was calculated for each of the two subgroups in the category Marinas and Shipyards/Terminals, with 50 species-lifestage combinations each, representing a total of more than 100 species-lifestage combinations for the box plot. Because the values for any given species and activity combination can range from 0 (zero) to the maximum reported, the box plot shows the full range of affected acreage for each species-lifestage/activity combination. Similarly, the box plot for the Overwater Structures group (five subgroups) represents data for more than 250 species-lifestage combinations. Table 2-6 provides an example of the appearance of the same data in tabular form.

## PRIORITIZATION PROTOCOL

The first task of prioritization was to generate a table containing potentially affected habitat values for each species-lifestage combination by activity group. Table 2-6 provides an abbreviated example of how these data appear in tabular format. Note that the maximum observed affected habitat area is presented in the lower right corner of the table.

The second task was to normalize the affected habitat area calculations, such that all values in the table ranged between zero and one. By transforming the data in this manner, it was possible to maintain the proportionality of the affected habitat area calculations for use in the prioritization protocol. This was accomplished by dividing all of the values in Table 2-6 by the maximum observed value. An example of the results of these calculations is presented in Table 2-7.

In the third task, the maximum score derived from Table 2-7 was identified for each species group. An example of this analysis is presented in Table 2-8. It was necessary to generate statistics for species groups rather than for individual species or lifestages, because the conservation measures were originally scored in this way in the Expected Outcomes analysis (see Washington DNR 2006 for details). This analysis could easily be modified in subsequent iterations of the prioritization protocol to give equal weight to each species rather than to combine the data by species group (e.g., bald eagle, black tern, etc. vs. birds).

The fourth task relates species group scores to specific conservation measures (examples provided in Table 2-9) and determines the final score for Step 5. All conservation measures associated with an activity group received the same score, regardless of the perceived effectiveness of the measure evaluated in Step 2. By applying the same score to all conservation measures associated with an activity group, it was possible to emphasize measures with the potential to address large-scale impacts in the prioritization process. The values in Table 2-9 were then used in the final ranking of conservation measures, which is described in greater detail in Step 7.

**Table 2-6. Calculate potentially affected acreage by species-lifestage and activity group.**

| Species-Lifestage | Activity 1 | Activity 2 | Activity 3 | Activity 4 | Activity 5 |
|---|---|---|---|---|---|
| Species X – Lifestage A | 39.3 | 1,508.4 | 1,418.6 | 1,994.7 | 483.3 |

| | | | | | |
|---|---|---|---|---|---|
| Species X – Lifestage B | 5.6 | 16.8 | 987.5 | 156.6 | 380.1 |
| Species Z – Lifestage A | 39.3 | 1,508.4 | 1,343.8 | 462.1 | 1,158.4 |

**Table 2-7. Normalized affected area values.**

| Species-Lifestage | Activity 1 | Activity 2 | Activity 3 | Activity 4 | Activity 5 |
|---|---|---|---|---|---|
| Species X – Lifestage A | 0.00 | 0.03 | 0.03 | 0.04 | 0.01 |
| Species X – Lifestage B | 0.00 | 0.00 | 0.02 | 0.00 | 0.01 |
| Species Z – Lifestage A | 0.00 | 0.03 | 0.03 | 0.01 | 0.02 |

**Table 2-8. Maximum score by species group (amphibians and Reptile, birds, fish, and mammals).**

| Species-Lifestage | Activity 1 | Activity 2 | Activity 3 | Activity 4 | Activity 5 |
|---|---|---|---|---|---|
| Species Group 1 | 0.00 | 0.03 | 0.03 | 0.04 | 0.01 |
| Species Group 2 | 0.00 | 0.03 | 0.03 | 0.01 | 0.02 |

**Table 2-9. Step 5 final score by conservation measure.**

| Activity | Conservation Measures | Species Group 1 | Species Group 2 |
|---|---|---|---|
| Activity 5 | Conservation Measure 1 | 0.01 | 0.02 |
| | Conservation Measure 2 | 0.01 | 0.02 |
| | Conservation Measure 3 | 0.01 | 0.02 |
| Activity 6 | Conservation Measure 4 | 0.79 | 1.00 |
| | Conservation Measure 5 | 0.79 | 1.00 |

# Step 6: Determine whether conservation measure applies to multiple activity groups

## OBJECTIVE

The objective of this step in the prioritization protocol was to identify and emphasize conservation measures that applied to more than one activity group. The rationale is that a monitoring program designed to evaluate responses for a structure that is similar to one in another activity group (e.g., docks in marinas and recreational docks) may provide information useful to both, or eliminate the need to monitor both subgroups.

### PRIORITIZATION PROTOCOL

If the conservation measure did not relate to more than one activity group, it received a score of one. If the potential for a conservation measure to apply to more than one activity group was high, the conservation measure received a score of 1.5, whereas if the potential was deemed low, the conservation measure received a score of 1.25. The numeric scoring convention used in Step 6 differs from those presented in previous sections and is a function of the way in which these scores were applied in the final prioritization algorithm. The intent of Step 6 was to give slightly greater weight to conservation measures with broad applicability to many activity groups. The computational methods used to accomplish this objective are described in greater detail in Step 7. However, if the conservation measure did not apply to multiple activity groups, the influence of the previous steps was undiminished. If the measure did apply to other activity groups, the scores from previous steps were slightly magnified.

**Table 2-10. Example of the prioritization protocol with respect to applicability of a conservation measure to multiple activity groups.**

| Conservation Measure | Multiple Activities |
|---|---|
| Site log storage areas and transfer facilities in areas with good currents and tidal exchanges. | 1 |
| Incorporate measures that increase the ambient light transmission under piers and docks. These measures include, but are not limited to, maximizing the height of the structure and minimizing the width of the structure to decrease shade footprint (replacement maintenance); grated decking material; using solar tubes to direct light under the structure and glass blocks to direct sunlight under the structure; illuminating the under structure area with metal halide lamps and use of reflective paint or materials (e.g., concrete or steel instead of materials such as wood that absorb light) on the underside of the dock to reflect ambient light. | 1.5 |
| Ensure that net pen structures have webbing of appropriate size to prevent entanglement by Covered Species and their prey. | 1 |

## Step 7: Prioritize conservation measures

### OBJECTIVE

The objective of this step was to use the results of the analyses performed in Steps 2 through 6 to determine the relative priority of each conservation measure.

### PRIORITIZATION PROTOCOL

Final ranking for individual conservation measures was determined by summing the scores from Steps 2 through 5. This sum was then multiplied by the score determined in Step 6. The conservation measures were then ranked according to these scores. The conservation measure with the highest score was identified as the highest priority for additional examination. Table 2-11 provides an example of the mathematics used to determine the summary scores. Note that based on the summation of Steps 2 through 5 alone, Conservation Measure 1 would have ranked highest. However, by emphasizing conservation measures that apply to multiple activity groups, Conservation Measure 2 was elevated to the highest priority position.

**Table 2-11. Example of prioritization protocol summary scores and conservation measure ranks.**

| Conservation Measure | Score | | | | Sum Steps 2 to 5 | Score | | Rank |
|---|---|---|---|---|---|---|---|---|
| | Step 2 | Step 3 | Step 4 | Step 5 | | Step 6 | Total | |
| Conservation Measure 1 | 3 | 5 | 4 | .02 | 12.02 | 1 | 12.02 | 2 |
| Conservation Measure 2 | 4 | 2 | 4 | 1.00 | 11.00 | 1.5 | 16.50 | 1 |
| Conservation Measure 3 | 1 | 3 | 2 | .03 | 6.03 | 1.25 | 7.54 | 3 |

# 3. Monitoring Program Design Overview

Chapter 2 of this document provides a process for evaluating and prioritizing conservation measures for examination in an effectiveness monitoring program. The paragraphs that follow present a step-by-step process for testing the efficacy of any given conservation measure. It should be noted that this process did not exist a priori, and that although some steps were self-evident, others did not emerge until after considerable deliberation. To the extent possible, each step in the process is illustrated by an example from our pilot studies. It is also important to consider that although the steps are presented sequentially, a certain amount of iteration is necessary and must be expected. The steps in this process are as follows:

- Step 1: Identify programmatic/institutional assets and constraints.
- Step 2: Define specific application of conservation measure.
- Step 3: Review conceptual understanding of potential ecosystem response.
- Step 4: Identify information gaps.
- Step 5: Identify potential monitoring parameters.
- Step 6: Select monitoring protocols.
- Step 7: Develop experimental design and statistical analysis.

## Step 1: Identify programmatic/institutional assets and constraints

Because natural systems are inherently complex, and because there are many variables involved, it is not possible to fully evaluate every proposed conservation measure for effectiveness. Therefore, an important first step is to identify institutional assets and constraints.

For this project, we examined three levels of resource allocation corresponding to the minimum effort specified by Washington DNR in the scope of work ($250,000 to 300,000/year), an expanded level of effort (≈$1,500,000/year), and unconstrained experimental effort (unlimited funding). Each level of effort is discussed in greater detail in Step 6. For the minimum recommended effort, it was assumed that approximately $30,000 would be available for evaluation of a single conservation measure. The ultimate experimental design, which is described in later sections, did not include costs associated with manipulation or alteration of physical structures (e.g., installation of prisms in overwater structure), equipment purchase, or hardware and software necessary for data analysis or reporting.

Other assumptions were as follows:

- Field measurements to be collected by Washington DNR staff.
- Field crew consists of three people.
- Average hourly rate equals $30/hour.
- Total per diem is $100/day.
- Mileage equals $0.45/mile.
- Travel is less than 200 miles/day.
- Field effort is 1 day per site.

Identification of programmatic and institutional assets and constraints is one of the most important steps in the design of an effectiveness monitoring program, because these factors largely determine the technical and analytical approach. For example, in this project, it became clear that $30,000 was sufficient to examine the effectiveness of a measure in only one (saltwater-nearshore) of the six defined ecosystems (Appendix D). Alternative assumptions regarding funding levels might have led to the selection of more or different monitoring parameters, or even a different experimental framework.

## Step 2: Define specific application of conservation measure

For a measure to proceed to the next step in the process, certain criteria must apply:

- The measure must lend itself to formation of a testable hypothesis.
- The measure must identify explicitly the features of the authorized use that will be manipulated in the experimental framework described in Step 7 of this chapter.
- Washington DNR must be willing to implement the treatment on its own, or through incentive programs, or as a condition of continued use.

### MEASURE 1: Increase the ambient light transmission under piers and docks or other nearshore areas

This conservation measure generally stipulates that opaque decks will be replaced with devices or structures that increase light transmission below an overwater structure. Because this measure ranked highest in the evaluation described in Chapter 2 and was also clearly implementable, given Washington DNR's proprietary authority, it was selected as the measure for which a field monitoring study would be developed.

## MEASURE 2: Use materials such as steel, concrete, recycled plastic, anchors, and elastic rods or alternative dock mooring systems when replacing structure parts during maintenance

This conservation measure generally stipulates that treated pilings will be replaced with nontoxic materials. This measure ranked second highest in the evaluation described in Chapter 2. However, investigation of the issues associated with treated wood impacts in aquatic environments, the parameters and analytical requirements associated with toxicity testing; and the high potential for confounding factors associated with surrounding conditions made evaluation of this measure impossible within the budget defined for this contract. Although the measure could be incorporated into the final HCP Effectiveness Monitoring Plan, doing so would significantly increase costs because of the expense associated with chemically "fingerprinting"[1] the source of polycyclic aromatic hydrocarbons (PAHs). Preliminary assessment information for the measure is provided in Step 3 of this chapter.

## MEASURE 3: Include low-wake vessel technology, appropriate routes, and best management practices for wave attenuation structures as part of the design and permit process

This conservation measure generally stipulates that low-wake vessel technology, appropriate routes, and best management practices for wave attenuation structures will be implemented as part of the design and permit process. This measure ranked fourth using the process described in Chapter 2. Several possible monitoring parameters with efficient measurement methods were identified to evaluate the effectiveness of this measure. However, difficulties associated with defining the role that Washington DNR could have in applying the conservation measure eliminated it from consideration for a pilot field study. The preliminary information gathered for assessment of the measure is presented in Step 3 of this chapter.

## MEASURE 4: Assess water drainage and runoff patterns and alter them to reduce direct inputs

This conservation measure ranked third in the evaluation described in Chapter 2, but was excluded from further consideration because of uncertainty regarding Washington DNR's authority to implement the measure, and difficulties associated with specifying the design changes necessary to implement the measure.

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[1] Fingerprinting is a forensic tool for evaluating environmental contamination, whereby a distinctive ratio or multiparameter chemical signature is discerned that can be used to characterize a contaminant plume from a particular source (Plumb 2004).

## Step 3: Review conceptual understanding of potential ecosystem response

One of the first critical steps that should be taken in preparation for evaluating a conservation measure is to develop a sound understanding of the issue the measure is designed to address. This is best accomplished by a focused literature review that includes journal articles, reports, and a survey of the unpublished work (gray literature) produced in the state. The information collected should be used to examine the important features of the issue that affect Covered Species and to build a conceptual model of the ways in which these species may respond to the changes sought by the measure.

### MEASURE 1: Increase the ambient light transmission under piers and docks or other nearshore areas

The degree to which light is reduced under overwater structures is related to several structural features. The most important are the height and width of the structure, its orientation, and whether or not the decking is a solid or opaque material (Table 3-1). This conservation measure suggests that structural features that can be incorporated during construction and maintenance of a structure, such as maximizing the height of the structure above water; minimizing the width of the structure; using concrete or steel pilings incorporating light transmission mechanisms into the decking (e.g., grating, glass blocks, solar tubes) may be effective ways of increasing light penetration under overwater structures. Blanton et al. (2002) studied the effectiveness of several approaches to increasing light transmission under overwater structures. Their study showed that grating was the most effective light transmission method, followed by solar tubes. The use of glass prisms was an effective light transmission method for docks that are less than 3 meters above the water surface (Blanton et al. 2002).

**Table 3-1. Dock features that affect light penetration[a] .**

| Dock Factor | Configuration | Shading Effect[b] | Reason | Ecological Effects Importance Rank |
|---|---|---|---|---|
| Height above water | High | + | A higher structure allows for more diffusion and refraction around dock surface than a lower structure | First |
| | Low | – | | |
| Orientation | North-South | + | The north south orientation allows varying shadow period as sun travels east-west throughout the day | Second |
| | East-West | – | | |

| Dock Factor | Configuration | Shading Effect[b] | Reason | Ecological Effects Importance Rank |
|---|---|---|---|---|
| Width | Small | + | A small footprint creates a smaller shadow area than a larger footprint | Third |
| | Large | – | | |
| Deck surface | Grating, light transmission blocks | + | Allows light penetration within inner areas of footprint | Unknown |
| | Solid | – | Light only penetrates at edge of overwater structures | |
| Piling density, placement | Low/open spacing | + | Low density, open spacing decrease shadows from pilings | Unknown |
| | High/close together | – | | |
| Construction material | Concrete/steel | + | Refracts light | Unknown |
| | Wood | – | Absorbs light | |

a - Adapted from Nightingale and Simenstad 2001.
b - + less light loss; – more light loss.

### Conceptual Model

Washington's Aquatic Habitat Guidelines Program (state Departments of Fish and Wildlife; Ecology; Natural Resources, and Transportation; Interagency Committee for Outdoor Recreation; US Army Corps of Engineers; US Fish and Wildlife Service) recently provided reviews of the issues associated with overwater structures in saltwater and freshwater habitats (Nightingale and Simenstad 2001, Carrasquero 2001). Both reviews described issues related to the interruption of key ecological controlling factors including substrates, water quality, wave energy, and light – the focus of this conservation measure. Both reviews identified the primary effects of reduced light under overwater structures as reduced plant growth (macrophytes and phytoplankton), and altered fish and invertebrate distribution and behavior. Although species-specific effects from reduced light were not noted for any group other than fish, both reviews identified reduced light as directly affecting only juvenile salmon (Nightingale and Simenstad 2001, Carrasquero 2001). Reduced light under overwater structures also could affect juvenile salmon predators indirectly, but establishing that link would involve consideration of confounding factors that are beyond the reasonable scope and budget of a conservation measure evaluation study. For example, it is thought, but not yet demonstrated, that light differences under structures could lead to increased predation on salmonids. To address that issue could require complex studies of predator behavior, occurrence, and diets, for example, in addition to monitoring salmonid behavior. Thus, the current effort will focus on evaluating the direct effects to juvenile salmon of reduced light under overwater structures.

Nearshore habitats are essential for many salmonid species for adult residence, adult and juvenile migration, and juvenile rearing, although use of the habitats varies somewhat by species and lifestage (Table 3-2). Therefore, the presence of overwater structures in nearshore habitat has the potential to adversely affect the Covered Species in a number of ways. The structures can reduce light reaching the water below, which can have an impact to juvenile salmon (Figure 3-1). Presence of overwater structures can contribute to decreased plant refuge and epibenthic prey (Haas et al. 2002); increased wave energy and turbulence associated with vessels using the structure; subsequent changes in benthic substrates; interruption of migratory behavior; and possibly a change in the aggregation of juvenile salmon predators (Simenstad et al. 1999, Carrasquero 2001, Southard et al. 2006b). Juvenile salmon are affected by the sharp contrast at the underwater boundary between the area shaded by the overwater structures and the open environment, although the significance of the behavioral changes is not known (Thom et al. 2005). Shading beneath overwater structures may cause juvenile salmon to become disoriented, disrupt schooling behavior, reduce feeding, and cause the salmon to swim to deeper waters (Simenstad et al. 1999).

**Table 3-2. Covered salmonid use of nearshore and estuarine habitat[a] .**

| Common Name | Scientific Name | Nearshore Marine and Estuary Use [a] | | |
|---|---|---|---|---|
| | | Adult Residence | Adult and Juvenile Migration | Juvenile Rearing |
| Bull Trout | *Salvelinus confluentus* | ● | ● | ● |
| Chinook | *Oncorhynchus tshawytscha* | ● | ● | ● |
| Chum | *Oncorhynchus keta* | ○ | ● | ● |
| Coho | *Oncorhynchus kisutch* | ⊕ | ● | ○ |
| Cutthroat | *Oncorhynchus clarki* | ● | ● | ● |
| Pink | *Oncorhynchus gorbuscha* | ○ | ● | ● |
| Sockeye | *Oncorhynchus nerka* | ○ | ● | ○ |
| Steelhead | *Oncorhynchus mykiss* | ○ | ● | ⊕ |

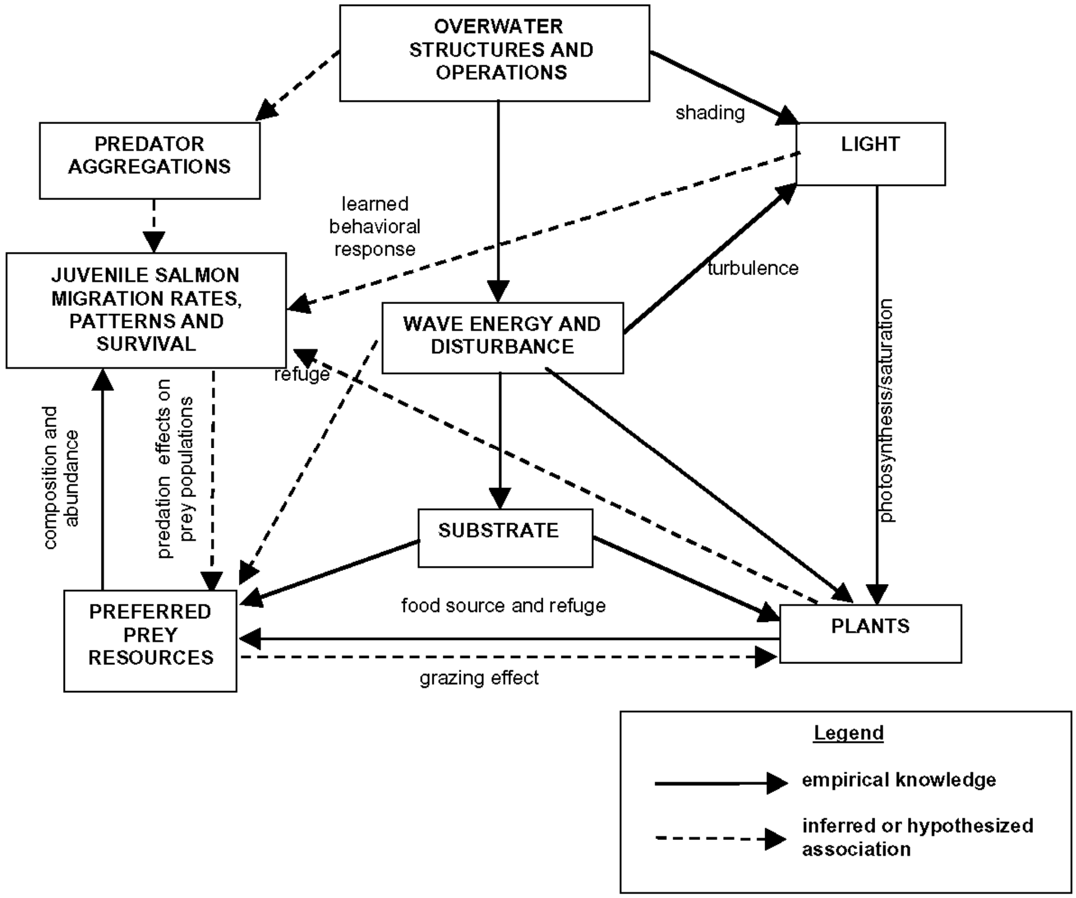
a - Adapted from Williams and Thom (2001).

b - Extensive use = ●, some use = ⊕, little or unknown usage = ○.

Carrasquero (2001), in his review of the effects of overwater structures on freshwater habitats, implied that one of the many impacts to juvenile salmon was likely attributable to the interruption of migration behavior by sharp changes in light under the structure. Although Carrasquero did not provide any direct evidence for such a problem in freshwater, he did cite estuarine examples described by Simenstad et al. (1999). There is some indication that migration patterns in some freshwater systems, such as larger rivers, may differ from those in estuarine systems. In a review of the effects of light on salmon migration on freshwater, Steel (1999) described several studies that reported increased downstream migration during the night, not only for juvenile salmon, but also for adults of some species. Steel’s review also showed that salmon lifestage may be important in explaining the difference in diel migration patterns, because younger salmon upstream in the Columbia River migrate mainly at night, whereas older salmon in the estuary of the Columbia migrate during the day. The implication of these observations is that overwater structures in some freshwater systems, such as larger rivers, may not affect salmon migration in the same manner that they do in estuarine and marine systems. Both Steel

(1999) and Carrasquero (2001) implied through their discussion that the nighttime increase in artificial light associated with overwater structures was the important factor potentially affecting salmon migration.

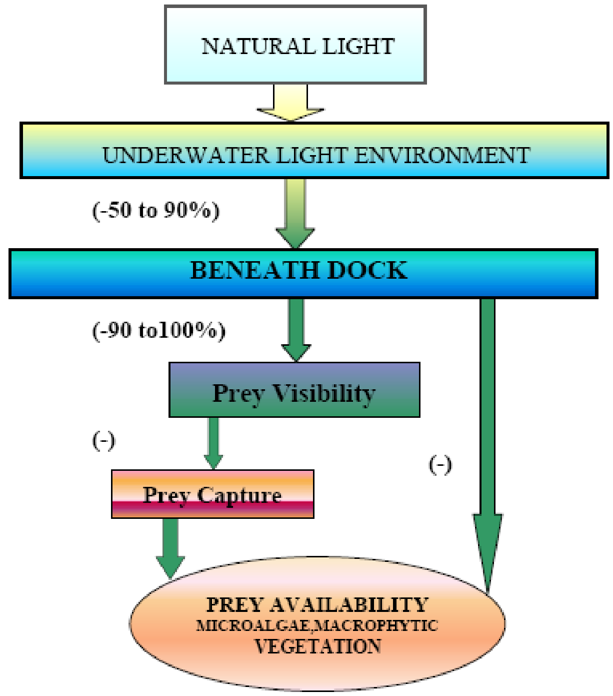
**Figure 3-1. Conceptual model of the mechanisms by which overwater structures affect juvenile salmon and nearshore habitats* .**




* Figure modified from Simenstad et al. (1999).

Reduced light beneath overwater structures in marine or estuarine waters also may affect juvenile salmon by reducing the available cover of submerged vegetation, particularly of eelgrass, *Zostera marina*. Although many factors influence the growth and distribution of eelgrass, the amount and quality of light is probably the single most important factor. Light is naturally attenuated as it passes through the water column, and light levels are reduced much further by overwater structures (Figure 3-2). This reduces eelgrass growth and productivity, diminishing the bed size under the overwater structures available to provide refuge for juvenile salmon. Reduced light also decreases epiphyte growth, which in turn reduces the epibenthic prey (copepods, amphipods) on which juvenile salmon feed (Haas et al. 2002). Carrasquero (2001) did not identify any specific studies of the impact of overwater structures shading on macrophyte communities in freshwater systems, but did infer that it is likely that shading decreases those communities as well.

## Figure 3-2. Conceptual model showing the sequential attenuation of light through the water column and underneath overwater structures[a]




a - Figure from Simenstad et al. (1999).

Blanton et al. (2002) evaluated three methods for increasing light transmission under overwater structures—grating, solar tubes, and glass (prism) blocks. They found that all three could provide an amount of light that should be adequate for eelgrass and macroalgal growth under the overwater structures in which they were installed. Although juvenile salmon need less light for migration than the amount necessary to support the growth of submerged vegetation, Blanton et al. (2002) pointed out that the light transmission system for the dock needs to provide a gradual transition between the open, unshaded area and the partly shaded region to avoid adverse effects.

### MEASURE 2: Use materials such as steel, concrete, recycled plastic, anchors and elastic rods or alternative dock mooring systems when replacing structure parts during maintenance

Chemicals released by treated pilings affect aquatic biota directly through contact with the medium and indirectly through food chain transfer (Table 3-3). Many of the effects probably depend on the amount of wood, its age, and the degree of flushing in the area.

## Table 3-3. Treated piling features that affect biota[a]

| .Treatment | Toxic Features | Exposure Medium | Route[b] | Effect | Exposure Occurrence; Duration |
|---|---|---|---|---|---|
| Creosote | PAH[c] (85%), phenols (10%), nitrogen- sulfur- or oxygenated heterocyclics | Water column | I | Reduced fish health | New, old pilings; short, long |
| | | Water column | I | Altered behavior - fish | New, old pilings; short, long |
| | | Water column | D | Acute toxicity - fish | New pilings; short |
| | | Water column | I | Chronic toxicity - fish | Uncertain |
| | | Sediment | I, D | Acute toxicity - invertebrates | New pilings; short |
| | | Sediment | I, D | Chronic toxicity - invertebrates | Old pilings; long |
| Metal-based (ACZA,[d] CCA[e] Type C) | Copper, zinc, chromium, arsenate | Similar to creosote; effects of CCA (and perhaps creosote) depend on amount of wood, its age, and amount of flushing in area | | | |

a -Table from Poston (2001).
b - D Direct via contact with medium; I Indirect via food chain transfer.
c - PAH Polycyclic aromatic hydrocarbon.
d - CCA Chromated copper arsenate (wood preservative).
e - ACZA Ammoniacal copper zinc arsenate (wood preservative).

Additional notes on the potential impacts from treated wood include the following:

- Creosote- and pentachlorphenol-treated wood are not allowed in freshwater lakes (Washington Departments of Ecology and Fish and Wildlife 1995).
- Pentachlorophenol is not used as a supplement to creosote-treated wood destined for marine applications in the Pacific Northwest.
- Effects are related to the size of the structure; at the scale of the Poston (2001) report, effects are small and limited to areas near structures.
- Hazards are greater for creosote treatment than for metal-based treatments (chromated copper arsenate [CCA] type C or ammoniacal copper zinc arsenate [ACZA]).
- Potential for water-column impacts is less than that for sediment-related impacts; Sooke Basin studies (Goyette and Brooks 1998, 2001) found that impacts in sediments occurred as far as 7.5 meters from creosote-treated structures and that

water-column effects were limited to the water surface; however, Goyette and Brooks did not identify the spatial extent of the water surface effects.

- The most likely exposure route for the selected Covered Species is trophic transfer.
- Separation of creosote-PAH from other sources may be difficult in contaminated sites; possibly resolved via PAH fingerprinting; also Sooke Basin studies showed that local contamination and other sources of PAHs could interfere with the identification of treated-wood effects.
- Much leaching has been shown to occur within a short time (to 7 days), but 40-year-old wood still shows significant effects (Vines et al. 2000).

Because of the confounding factors and budgetary constraints described earlier in the chapter, no formal conceptual model was developed for this measure.

### MEASURE 3: Include low-wake vessel technology, appropriate routes, and best management practices for wave attenuation structures as part of the design and permit process

In the initial evaluation of the low-wake conservation measures, two major impacts to Covered Species were identified with vessel wakes—fish stranding and habitat disruption. Wakes generated by large, deep-draft vessels often translate into relatively strong waves as they encounter shorelines, directly impacting juvenile salmonids and other small fish by stranding them on exposed beaches (Ackerman 2002, Pearson et al. 2006). Indirect impacts include shoreline erosion and increased turbidity in nearshore waters, which reduce the light available for submerged macrophytes (Asplund 2000). Smaller, fast vessels may cause similar impacts to shallower nearshore areas, although the incidence of fish strandings is not documented. Because of the direct impacts to Covered Species, the fish stranding impacts resulting from wake generation will be evaluated here. Although most, if not all, of the studies of fish stranding by wakes have focused on wakes generated by large, deep-draft vessels in the Columbia River Basin (Ackerman 2002, Pearson et al. 2006), the impacts and methods by which they are measured are very likely applicable to smaller vessels and water bodies, but at a reduced scale.

Pearson et al. (2006) described many features of wakes that potentially affect strandings (Table 3-4). Their study showed that vessel size and speed, the extent of the wake run-up on shore, fish presence, tidal height, and the location where the wake encounters the shoreline were the most important factors in determining the likelihood of stranding. Small vessels also may generate wakes that affect Covered Species through shoreline erosion and disturbance of nesting and foraging. Important factors determining the effects of these wakes are vessel and engine size, the amount of traffic in the area, and the size of the channel through which the vessels are passing (Table 3-4).

Vessels generate several types of wake-waves (Figure 3-3). Water passing along the bow accelerates and raises the water surface above its still-water level forming a short-period bow wave that diverges from the sailing line (Sorenson 1997, Pearson et al. 2006). The accelerated water is lowered as it passes along the side of the vessel, and a transverse stern wave is generated by return pressure and separation at the stern (Pearson et al. 2006). The highest waves occur where the transverse and diverging waves intersect (cusp locus line; Figure 3-3). Vessels moving in a channel also generate long-period draw-down waves, if the vessel draft is about half the depth of the channel and a relatively large volume of water is displaced (Pearson et al. 2006).

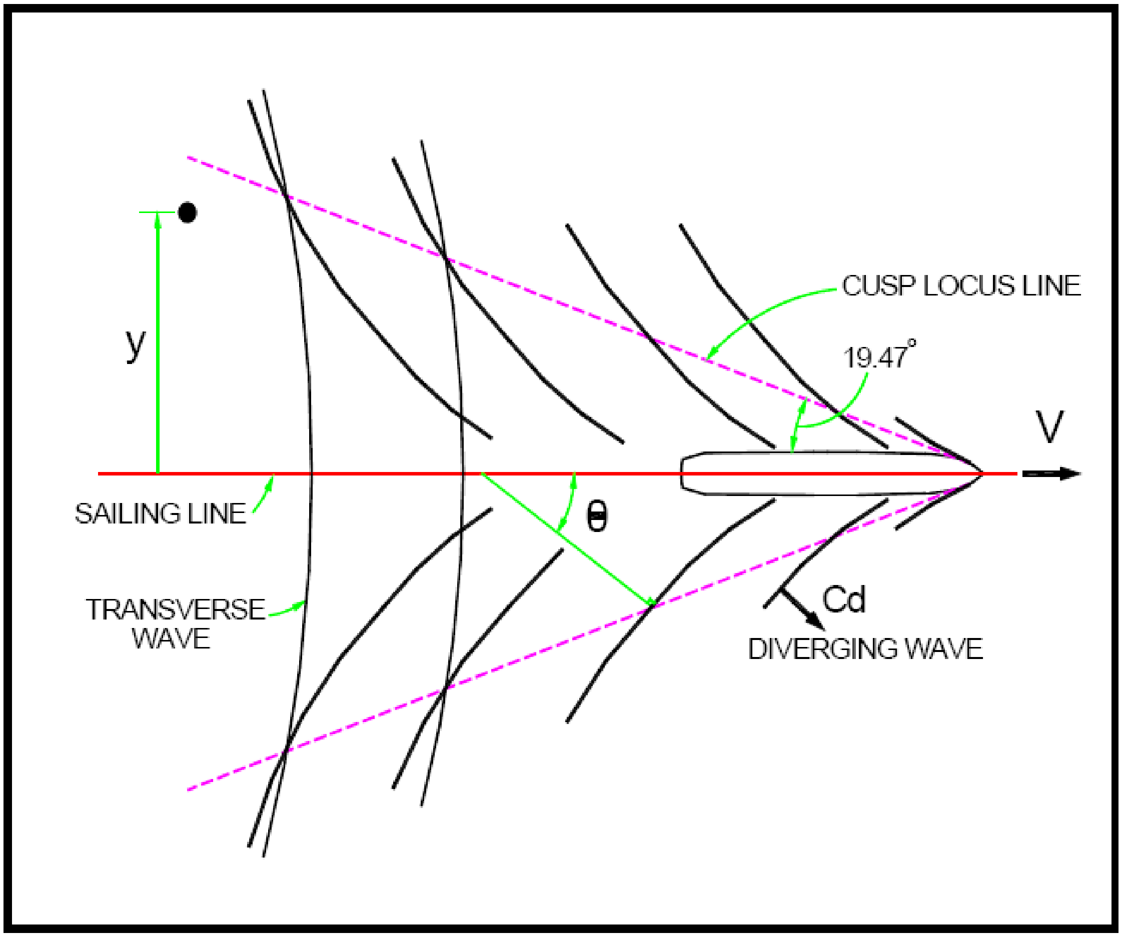
**Table 3-4. Factors affecting wake development and potential strandings of small fish, shoreline erosion, and habitat disturbance in nearshore waters[a] .**

| Factor | Feature | Fish Stranding | Shoreline Erosion or Habitat Disturbance | Relative Ecological Importance |
|---|---|---|---|---|
| Traffic | Number of boats | | Higher number of boats increases impacts | High |
| Vessel | Size/speed | Larger/faster vessel has greater kinetic energy; speed more important, higher stranding probability | Affects vessel speed, planing attainment: Displacement speed equals slow speed, low wake; transition speed equals largest wake; planing speed equals intermediate wake | High |
| | Type | Oil tankers, higher proportion strandings | Affects vessel speed, planing attainment | High |
| Wake/wave | Height | May lead to greater run-up | Higher waves have greater effects | High |
| | Period | Unknown | Unknown | Unknown |
| | Speed | May lead to greater run-up | May lead to greater run-up | Unknown |
| | Run-up extent | Greater extent, greater stranding | Greater run-up extent,less impact; wake dissipates better than versus steep beach | High |
| Channel | Water depth | Shallower water generates greater flow acceleration and pressure gradient; larger wakes[b] | Greater water depth, less effect | Unknown |

| Factor | Feature | Fish Stranding | Shoreline Erosion or Habitat Disturbance | Relative Ecological Importance |
|---|---|---|---|---|
| | Cross-section | Narrow water body generates greater flow acceleration and pressure gradient; larger wakes[b] | Narrower cross-section, greater erosion potential | High |
| Fish | Presence | Greater numbers, greater effect; seasonal availability for salmon | Not Applicable | High |
| | Size | Smaller size, greater potential for stranding | Not Applicable | Unknown |
| | Lifestage | Younger stages more susceptible[c] | Not Applicable | Unknown |
| Beach | Slope | Lower beach slope, greater distance for stranding | Higher slope, greater effect | Unknown |
| | Distance to channel | Closer to channel, greater effect | Closer = greater effect | Unknown |
| | Substrate | Unknown | Unconsolidated substrate, greater effect | Unknown |
| | Vegetation | Unknown | Vegetation can reduce effects of wakes | Unknown |
| River | Stage | Unknown | Unknown | Unknown |
| | Tidal height | Low tide = higher stranding probability | Unknown | High |
| Site | Location on water body | Local, fine-scale shoreline features such as presence/type of armoring affects other factors, such as water height; fish availability | Local, fine-scale shoreline features such as presence/type of armoring affects other factors, such as water height | High |

a. From Asplund (2000) and Pearson et al. (2006), except as noted.
b. Sorenson (1997).
c. Wolter and Arlinghaus (2003).

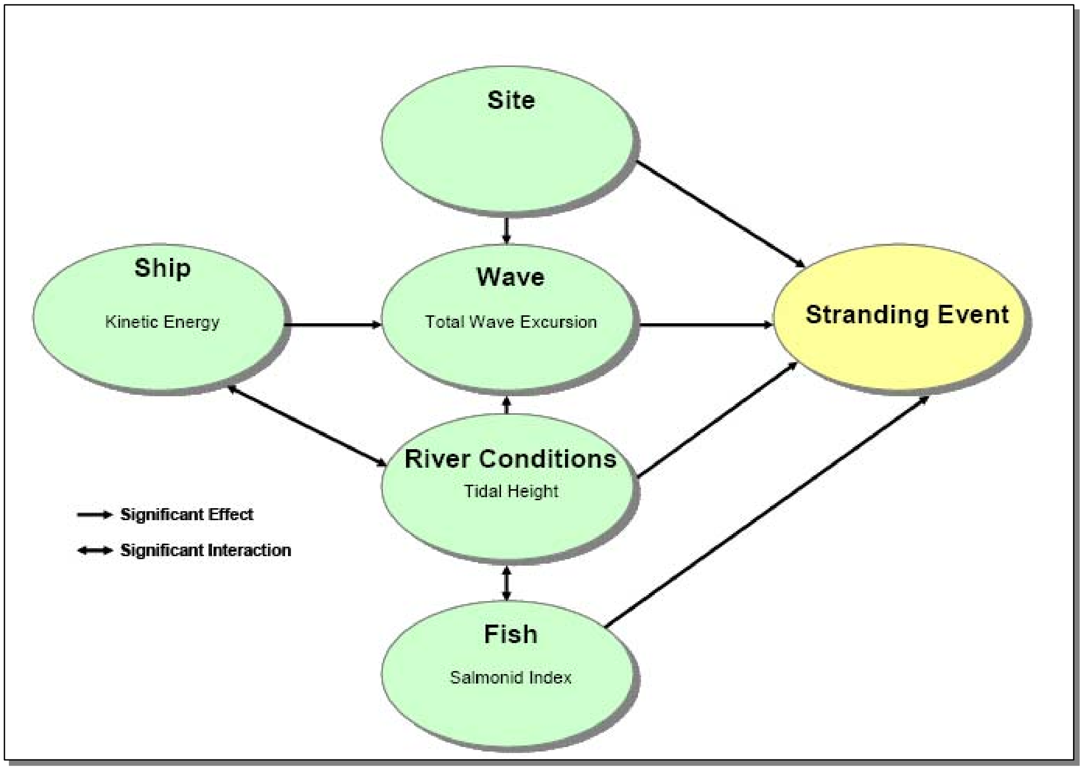
**Figure 3-3. Generalized short-period wake pattern generated by a vessel moving through a channel* (sailing line is the path of the vessel; "V" is the vessel speed; "Cd" is the speed of the diverging wave; "θ" is the angle of divergence away from the sailing line; the cusp locus line marks the point of intersection of the transverse and diverging waves; "y" is the distance of the locus from the sailing line).**




* Figure from Pearson et al. (2006).

Waves generated by a ship travel at the same speed as the ship and may cause considerable draw-down and run-up on shore, depending on the beach slope (Pearson et al. 2006). Pearson et al. (2006) conducted a detailed field study of stranding from large-vessel wakes at three sites on the Columbia River. The results of the study led to the development of a conceptual model (Figure 3-4) describing the important factors that increase the likelihood that fish strandings would occur.

## Figure 3-4. Conceptual model of fish strandings by ship wakes* .




* Figure from Pearson et al. (2006).

Although no formal conceptual model was developed to link small vessel wakes to effects to Covered Species or their habitats, such a model should be generally similar to that shown for large vessel wakes.

# Step 4: Identify information gaps

As part of the adopted HCP, Washington DNR will likely implement conservation measures in very different ecosystems (e.g., nearshore consolidated habitats versus low-gradient valley rivers) on the state-owned aquatic lands that Washington DNR leases for use by other entities. The effectiveness of certain measures has been demonstrated in either context-specific circumstances or across circumstances, but the widespread applicability of most measures remains uncertain. In addition, the implemented measures may be perceived by those leasing aquatic lands from Washington DNR, and by adjacent landowners as overly expensive to implement and/or generally undesirable. The intent of Step 4 is to eliminate aspects of measures for which there is great certainty and to focus additional work on addressing areas of uncertainty.

Because of the confounding factors associated with determining the effectiveness of conservation measures discussed earlier, and the budgetary constraints of the present contract, only Measure 1 (increase the ambient light transmission under piers and docks or other nearshore areas) was carried through the rest of the design process.

### MEASURE 1: Increase the ambient light transmission under piers and docks or other nearshore areas

Most, if not all, of the studies evaluating the effects of reduced light transmission beneath overwater structures have focused on larger structures, such as ferry terminals. Little is known about the potential impacts to habitats under smaller recreational structures, or about the potential compounding effects of many closely spaced structures. There is considerable speculation about the potential effects of overwater structures to increased predation on juvenile salmon, yet there is little evidence of the relationship between light reduction beneath overwater structures and predation on juvenile salmon. This is particularly true for freshwater systems for which there seems to be much less information about the effects of light reduction in general. There is also some evidence that overwater structures and the consequent reduction of light under them in freshwater may have effects on juvenile salmon that differ from those in marine and estuarine waters. However, there have not been any attempts at comparative studies that build an overall conceptual model of the effects of overwater structures throughout all phases of salmonid life cycles. Without such a holistic evaluation, the general applicability of specific conservation measures across ecosystems will remain uncertain.

No information was found that addressed the potential effects of reduced light under overwater structures on amphibians, particularly those identified as Covered Species by Washington DNR (Table 2-3). The three Covered Species of amphibians, the Columbia spotted frog (*Rana luteiventris*), the northern leopard frog (*Rana pipiens*), and the western toad (*Bufo boreas*), occupy nearshore freshwater ponds, lakes, or rivers that could be affected by overwater structures. The northern leopard frog and western toad may be more susceptible to the effects of overwater structures, because their egg masses are attached to aquatic plants in nearshore areas illuminated by sunlight (McAllister et al. 1999, O'Neil et al. 2001), which could be affected by reduced light beneath overwater structures. The Columbia spotted frog may be less affected, because its egg masses are only weakly attached to plants for a short time and soon float to the surface (Gourley et al. 2002). Thus, overwater structures may have important effects on the survival of all three species, but those effects have not been determined empirically.

## Step 5: Identify potential monitoring parameters

### MEASURE 1: Increase the ambient light transmission under piers and docks or other nearshore areas

The types of data that need to be collected and recorded to evaluate conservation measures include general site information, physical characteristics of the habitat, and biological measurements for the species of interest. Although the measurement of every parameter is not required for the evaluation of every overwater structure, each study should consider the specific features of the structure and water body being studied and select those parameters that will provide important, relevant information. Although many of the measurement methods generally are broadly applicable within a particular ecosystem, there may be situations for which alternative measures must be employed. For example, it is not possible to use a Secchi disc to measure water clarity in shallow, fast-moving streams or rivers, but a horizontal black disc could be substituted (Davies-

Colley 1988). A useful step in the process is the preparation of summary parameter matrices: typically, one for physical and one for biological parameters. These matrices include a rationale for the utility of a parameter, the methods by which it may be measured, and any constraints or other notes about its implementation.

It is important that field efforts be arranged and coordinated with the management responsible for the operation of the site. Field measurements should be taken during times of minimal or no activity at the overwater structures to ensure the safety of the field crew and to reduce the potential interference of the activity with the biological observations. For example, work at a ferry terminal should be done when the ferry is not at the terminal and should stop sufficiently in advance of ferry arrival to allow the field crew to safely exit the area. Other considerations in planning surveys, such as timing the sampling periods, are mentioned in the following text that discusses specific field methods.

### General Site Characteristics

General site characteristics should be observed and noted; they are useful for the interpretation of biological and physical data collected during the study (Table 3-5). General climatological data are also useful to understand the intensity of light available to the system at the specific time of the study. Information about the structure should include its orientation, physical dimensions (e.g., length, width, height, pilings), any ancillary structures that could affect light transmission (walkways, skirting), and a complete description (e.g., number, type, location) of the types of light transmission devices in place (Table 3-5). Photo documentation is a useful way to record many of the site characteristics. Observations of the principal activity conducted at the overwater structures, including an estimate of the frequency at which the activity occurs, is important for the interpretation of the biological data collected and to help ensure the safety of the field crew.

**Table 3-5. General site information that may be required for evaluating the effectiveness of the conservation measure to increase light under overwater structures.**

| Information | Parameter | Reason | Method |
|---|---|---|---|
| General | Calendar date | Season determines angle of sun, which affects light transmission; fish migration | Visual observation |
| | Time of day | Determines angle of sun, which affects light transmission; may affect fish migration or other behavior | Visual observation |
| | Field crew members | Crew members can be contacted should questions about the recorded data arise | Sign-in list |
| Weather | Cloud cover (type, percentage) | Affects available light intensity | Visual observation |

| Information | Parameter | Reason | Method |
|---|---|---|---|
| | Rainfall | Affects available light intensity and ability to observe fish | Visual observation (descriptive) |
| | Wind direction, approximate speed | Affects surface chop (direction, size) | Visual observation (descriptive) |
| | Water surface conditions | Affect visibility from above surface; may affect light transmission underwater | Visual observation (descriptive) |
| Structural | Activity (type, frequency) | Affects fish activity, plant habitat; field crew safety | Visual observation; management data |
| | Length, width, height, construction material | Affect degree of shading under structure | Visual observation (categories, direct measurements); permit information |
| | Pilings (spacing, type) | Affect degree of shading under structure | Visual observation |
| | Ancillary structures (walkways, skirting) | Affect degree of shading under structure | Visual observation; permit information |
| | Orientation (north-south, east-west) | Affects available light under overwater structures | Visual observation |
| | Light transmission devices (number, type, size, location) | Affect light transmission under overwater structures | Visual observation; permit information |
| Other | Substrate composition | May affect type of plant that can live under specific overwater structures | Visual observation |
| | Wave/stream energy | May affect ability to observe fish; may affect fish movement | Visual observation |
| | Tidal elevation, lake/river stage | May affect light under overwater structures (e.g., high tide reduces effective height of dock, reducing light) | Published records; US Geological Survey flow records |
| | Shoreline shading (vegetation, hill slope, buildings) | May confound (exacerbate) effects of overwater structures | Visual observation |

**Physical Parameters**

Physical parameters are important to measure because they could be directly related to the conservation measure of interest (in this case, light) and because their measurement could help explain potential confounding factors. Light is the primary physical measure required for evaluation of the light conservation measure (Table 3-6). Light measurements may include two types of data: *irradiance* measures photosynthetically active radiation (PAR), which includes the wavelengths necessary for plant photosynthesis; *illumination* is an indication of the light available for animal vision.

Other potential physical measurements are water temperature, clarity, and salinity or conductivity (Table 3-6). These parameters are routine, typically do not require substantial laboratory analyses, and are reasonably cost-effective to measure. It may not be necessary to measure all of the parameters presented for each overwater structure.

**Table 3-6. Physical parameters that may be required for evaluating the effectiveness of the conservation measure to increase light under overwater structures.**

| Data | Parameters | Reason | Method |
|---|---|---|---|
| Light | Irradiance (PAR) | Demonstrates whether or not measure has increased light under overwater structures; direct effect on plants | Spherical quantum light meter |
| | Illumination (lux) | Demonstrates whether or not measure has increased light under overwater structures; light available for fish vision | Photometric light meter |
| Water | Temperature | Affects plant growth | Thermometer; CTD[a]; YSI Sonde or similar in situ device |
| | Salinity (marine, estuarine) | Affects plant growth | YSI Sonde, refractometer, or similar in situ device |
| | Alkalinity, hardness, pH, conductivity (freshwater) | Affects plant growth | YSI Sonde or similar in situ device; water sample collection, commercial kits |
| | Clarity | Affects light transmission; affects salmon migration (particularly in freshwater systems) | Secchi disc; horizontal black disc (fast-moving waters [Davies-Colley 1988]); nephelometer; suspended solids |
| | Water depth | Plant distribution changes with small-scale depth changes; affects light transmission | Echosounder; depth gauge; leaded, marked line |

a - Conductivity, temperature, and depth measurement device.

### Biological Parameters

The two primary effects described earlier (reduced plant production, altered fish behavior) led to several potential biological monitoring pathways (Table 3-7). Because the primary concern identified for overwater structures was the effect of reduced light directly on the salmon, particularly juveniles, the primary monitoring should focus on this species group and lifestage. Thom et al. (2005) summarized the current wisdom concerning the use of nearshore habitats by juvenile salmon as out-migration corridors, which is a relatively restricted seasonal activity. Although most salmon use nearshore habitats from March through June, Chinook may be common there from January through September.

Directly monitoring juvenile salmon in the vicinity of overwater structures can be accomplished by observers on shore or in the water, or by remote methods (Table 3-7). Many of the important parameters can be measured without extensive lab work. Significant observations of juvenile salmon behavior can be made by snorkelers or shore-based observers wearing polarized sunglasses and using relatively nonintrusive methods (Williams et al. 2003, Southard et al. 2006b). Shore-based observations are generally limited to gross observations, such as the presence of and relative sizes of a school of more common species such as chum, for example. Snorkel surveys, although requiring more specialized observers, provide more detailed information on species composition, approximate length, position in the water column, and behavior (Southard et al. 2006b). Beach seines and enclosure nets provide for detailed quantitative counts of the species present, but involve some risk to the fish, even though fish are returned to the water after identification and measurement. Diver or snorkeler observations at night may be difficult to implement effectively because of the potential confounding effects of the artificial lighting required by the observers. Acoustic methods, such as fish tagging or a Didson camera, provide for counts of fish when direct observations are difficult (night, adverse weather), but require specialized equipment, or in the case of tags, microsurgical skills and substantial fish handling (Southard et al. 2006b).

**Table 3-7. Matrix of biological effects related to light limitation under saltwater and freshwater overwater structures, possible monitoring parameters, and methods.**

| | Effect | Parameter Monitored | Method | Measurement Importance | Constraints/ Notes |
|---|---|---|---|---|---|
| Eelgrass, freshwater macrophytes | Lower production | Growth | Leaf extension (marked leaf); chlorophyll ratios; leaf area; leaf phenology | Secondary | Divers; some lab measurements after collection |
| | Plant loss | Density; total abundance; percentage cover | Quadrat counts—whole plants; shoots; cover estimates; underwater video | Primary | Often high variability, especially with density; divers, no lab |

| | Effect | Parameter Monitored | Method | Measurement Importance | Constraints/ Notes |
|---|---|---|---|---|---|
| | Reduced "function" | Epibenthos density | Pump samples; net samples | Secondary | Haas et al. (2002) found eelgrass patch within influence of overwater structures had low epibenthos (juvenile salmon prey); diver collection; lab intensive |
| Epiphytic algae | Lower production | Growth | Oxygen flux in chambers Ash-free dry weight (AFDW) biomass/time | Secondary | Diver collection; lab intensive; some uncertainty about effect |
| | Plant loss | Biomass/ diversity | AFDW biomass; species numbers | Secondary | Diver collection; lab intensive; some uncertainty about effect |
| | Reduced function | Epibenthos density | Pump samples | Secondary | Diver collection; lab intensive |
| Juvenile salmon | Reduced prey | Meiofauna/ macrofauna species, abundance | Pump samples | Secondary | Not clear if from light alone; indirect via loss of habitat (epiphytes) (Haas et al. 2002). *Note: important to measure categories other than eelgrass; diver collection; lab intensive* |
| | Reduced foraging | Feeding behavior | Observations (remote video; snorkel surveys); fish gut contents; caged experiments | Secondary | Light reduces visibility of prey; divers; lab work. *Caution: salmon species differ in sensitivity* |

| | Effect | Parameter Monitored | Method | Measurement Importance | Constraints/ Notes |
|---|---|---|---|---|---|
| | Migration interruption—day | Swimming behavior/ counts/ schooling behavior | Observations (remote video; snorkel surveys; shore-based visual surveys); in situ counts; acoustic tracking (tags, Didson Camera); beach seines, nets | Primary | Seasonal: most species March through June, Chinook January through September; divers or snorkelers. *Caution: salmon species differ in activity patterns and timing, individual salmon also show variation* |
| | Increased mortality risk—day | Swimming behavior/ counts/ schooling behavior/ reduced refuge | Observations of increased predation rates (remote video; snorkel surveys; shore-based visual surveys); in situ counts; plant surveys; fish gut contents | Secondary | Forced to swim deeper to go around overwater structures/ not much evidence on predation risk; divers or snorkelers; lab work |
| | Migration interruption—night | Swimming behavior/ counts/ schooling behavior | Observations (remote video); acoustic tracking (tags, Didson Camera) | Primary | Artificial light at overwater structures creates nighttime effects similar to day; light an attractant, including predators; measures to increase day lighting also increase night lighting; interrupts migration in fresh water; divers or snorkelers |

| | Effect | Parameter Monitored | Method | Measurement Importance | Constraints/ Notes |
|---|---|---|---|---|---|
| | Increased mortality risk— night | Swimming behavior/ counts/ schooling behavior | Observations of increased predations rates (divers, snorkel surveys) | Secondary | May be difficult to observe because of confounding effects of introduced artificial lighting needed by divers |

## Step 6: Select suggested monitoring protocols

The selection of monitoring protocols is heavily dependant on institutional assets and constraints identified in Step 1 of this process. Consequently a certain amount of iteration may be expected as efforts are made to optimize the nature and volume of information acquired in the field effort. For example, all of the monitoring protocols associated with treated wood pilings were expensive. It was not possible to design a defensible monitoring program consistent with the assumptions specified in Step 1.

### MEASURE 1: Increase the ambient light transmission under piers and docks or other nearshore areas

The protocols presented here are designed to monitor the two most important outcomes of increasing the transmission of light under overwater structures: reduction of the juvenile salmon migration barrier, and enhanced vegetation beds (eelgrass of freshwater macrophytes). The procedures described are primarily derived from the sampling programs conducted to investigate the effects of light reduction associated with Washington State ferry terminals on juvenile salmon and eelgrass (Williams et al. 2003, Southard et al. 2005, Thom et al. 2005, Southard et al. 2006b).

Whereas the protocols described in the following sections should be generally applicable to monitoring around any overwater structures, their application may need to be modified according to special characteristics of each structure considered. Therefore, the applicability of each protocol or sampling design needs to be verified for any structure monitored. It is also important to consider the use of the overwater structures when conducting the survey, not only because of the potential confounding effects of activity associated with the structure on the measured parameters (e.g., fish behavior), but also to ensure the safety of the field crew (Williams et al. 2003).

#### Light

The measurement of light requires the use of an appropriate light meter and is relatively simple. Examples of specific light meters are provided, although other models may be suitable. PAR can be measured by using a LI-COR LI-193SA spherical quantum sensor, which gathers light information from all directions above a surface on which the sensor is placed. PAR includes the light spectrum between 400 nm and 700 nm and is measured as micromoles of photons per square meter per second ($\mu mol/m^2/s$). Illumination can be measured by using a LI-COR LI-210SA photometric sensor, which detects light from directly above the sensor and is measured as lux, the number of lumens (lm) that strike one square meter of surface. Both sensors may be operated by a field crew member and the data recorded by hand, or they may be connected to a LI-COR Model 1400 data logger, which can be set to collect data at 15-second intervals and to record the mean values at 1-hour increments to provide a continuous record of light transmission (Southard et al. 2005).

The placement of the light meters can depend on the specific overwater structures' design and orientation and the specific question addressed. They are typically placed in air and in water sites. These locations need to be determined during the final survey design. Southard et al. (2005, 2006b) provided examples for locating the light sensors to study the effects of light on eelgrass, as follows:

- Off the south side of the overwater structures in ambient lighting conditions (ambient conditions, in air, not shaded);
- Under the overwater structures on the north side (in air, shaded);
- Off the south side of the overwater structures (unshaded, in water, just above the substrate at eelgrass depth);
- Under the overwater structures on the north side (shaded, in water, just above the substrate at the same depth as the location described in Bullet 3, above); and
- Measurements may be taken at about 2-meter intervals near (<10 meters) and under the overwater structures, but can be as far as 10 meters apart when measured away (>10 meters) from the structure.

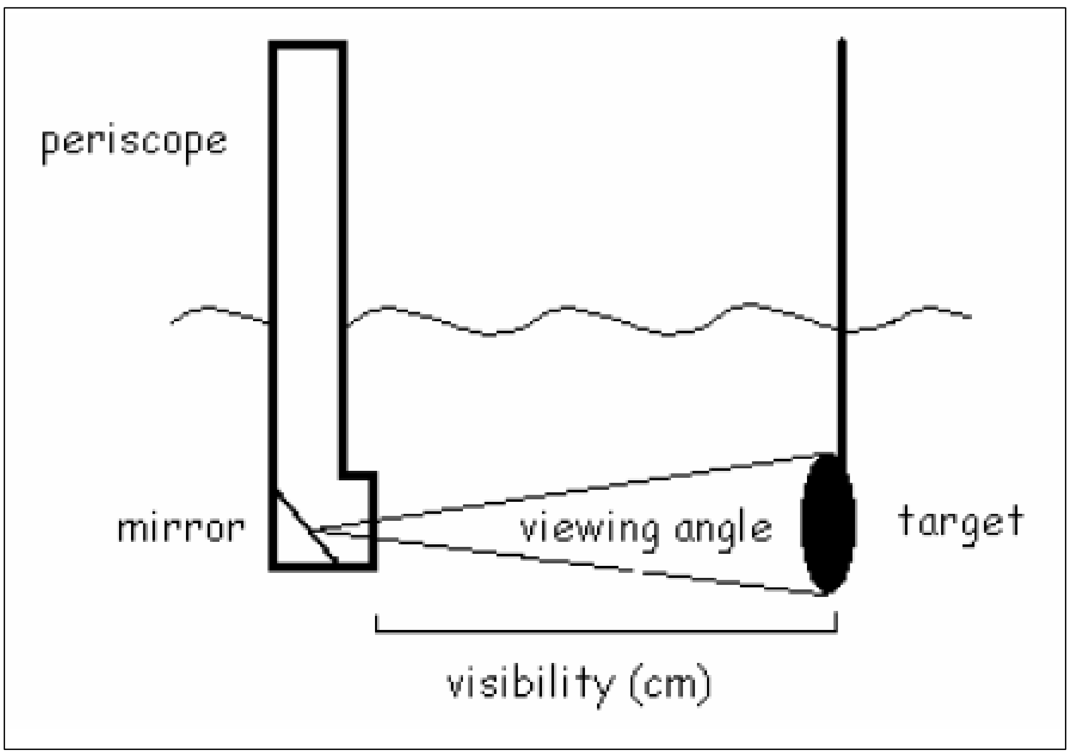
The above notes are provided as an example of one type of study (i.e., eelgrass). Sensor placement, at least within the water column, would certainly differ for studying light in conjunction with juvenile salmon migration. For example, there may be no need to place sensors near the substrate, but there may be a need to place sensors at relatively close intervals in the transition zone between light and dark at the edge of the structure. The specific placement of the sensors depends on the focus of the study (e.g., fish versus eelgrass) and the type and location of the structure being evaluated (determines width of transition zone and extent of dark zone under structure).

### Other Physical Parameters

Although all of the other physical parameters that may be useful to help interpret the biological data collected can be measured by using a range of methods that vary in cost and complexity, most can be effectively measured by relatively simple, cost-effective techniques. Usually a high degree of accuracy is not required for these types of measurements. Temperature may be adequately measured by using a hand-held digital thermometer. Salinity can be measured to an accuracy of about 1 practical salinity unit (PSU; roughly equivalent to parts per thousand) by using a refractometer. Other water quality parameters, such as alkalinity or hardness, can be measured by collecting a small sample of water and using a commercially available testing kit. For example, Hach test kits that can be used to measure several water quality parameters are available at a variety of accuracy levels and prices.

Water clarity is closely associated with light penetration and can be measured simply by using a Secchi disc, although the Secchi-disc measure is not a direct measurement of an optical property of the water (Steel 1999). However, this approach cannot be used in shallow or fast-moving waters. Davies-Colley (1988) developed a horizontal black disc to measure water clarity where a Secchi disc could not be used. The disc is placed such that its face is beneath the water surface and perpendicular to it. An inverted periscope is used to observe the disc and to determine the distance at which it is no longer visible (Figure 3-5). This technique allows measurement of water clarity in a manner that is similar to a beam attenuation measurement, because the disc does not reflect light (Steel 1999). Steel (1999) developed an alternative approach by making the disc black and white, similar to a traditional Secchi disc, and using it in place of the horizontal black disc. Steel determined that both disc approaches worked similarly under most weather conditions. He found that rainfall affected the black disc measurements, but not the horizontal Secchi disc measurements, for reasons that were not clarified (Steel 1999). Both horizontal discs were affected by user experience; the periscope is somewhat awkward to use, and a degree of teamwork between the holder of the periscope and the holder of the disc is required. Nonetheless, Steel stated that either horizontal disc was a good option for measuring water quality in fast-moving waters.

**Figure 3-5. Horizontal black disc used for measuring water quality*.**



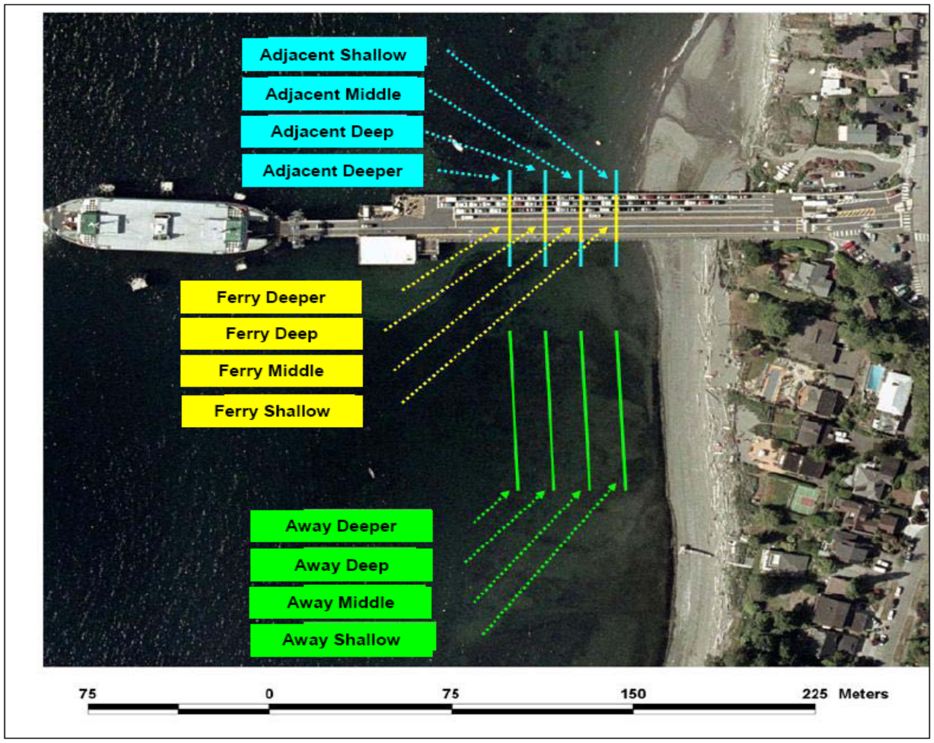

* Figure from Steel (1999).

### Fish Occurrence and Behavior

Two basic types of survey methods will be useful for evaluating potential changes in migrating juvenile salmonid behavior near overwater structures. Both methods are nondestructive visual observations and do not involve the collection of fish. However, salmonid species identification may not be possible without some type of collection activity.  The primary method is water-based and involves snorkeling by the field crew. Crews swim along several preset transects that are aligned approximately parallel to shore and follow varying depth contours (Southard et al. 2006b; Figure 3-6).  Snorkel surveys are designed to include high- and low-tide periods.  At least three transect locations should be included in the design—one underneath, one adjacent to, and one that begins about 30 m away from the overwater structures and continues in a direction away from the structure.  The actual length of the transects depend on the size of the overwater structures evaluated.  Snorkel surveys require relatively good underwater visibility (Southard et al. 2006b); for example, Secchi disc readings should be >2.5 meters (Toft et al. 2004).  Data collected could include the following:

- Fish species identity (if possible) and abundance (direct counts or by defined category);
- Approximate length (2.5-centimeter categories);
- Approximate location in water column;
- Fish behavior (e.g., feeding, active swimming, predator avoidance, shadow avoidance); and
- Salmonid location in relation to the overwater structures (e.g., under, within 10 meters, farther than 10 meters of the overwater structures).

**Figure 3-6.  Example of snorkel transect locations to be followed for observing juvenile salmonids (Fauntleroy Ferry Terminal)*.**




* Figure from Southard et al. (2006b).

The secondary method is shore-based and calls for the field crew to walk along the shoreline looking for juvenile salmon, which typically swim along the surface of the water (Southard et al. 2006b). Field crew members should wear polarized sunglasses to reduce glare off the water surface and enhance the fish visibility. Observations can be made from shore or from the overwater structures. Data could include the following:

- Salmonid location in relation to the overwater structures (e.g., under, within 10 meters, farther than 10 meters of the overwater structures);
- School size and approximate position in water column; and
- Fish behavior (e.g., feeding, active swimming, predator avoidance, shadow avoidance).

This observation method is less reliable than snorkel surveys, because fish may be more difficult to observe from shore and species identifications are difficult to make. Additionally, in some evaluation situations, an appropriate reference site may not be available. For example, observations from a shoreline that is not near an overwater structure would not be an appropriate reference site for comparison to observations made from an overwater structure that has been modified. Nonetheless, there are situations for which this observation method could be useful. For example, direct comparisons between modified and unmodified overwater structures could be made if the structures compared were very similar in size, shape, and construction materials, and were located in comparable environments. This method is simple and cost-effective, but its obvious constraints dictate that its use must be carefully considered.

### Eelgrass/Macrophytes

The following method descriptions are based primarily on surveys conducted to monitor the condition of nearshore/estuarine eelgrass beds; however, their principles should be generally applicable to monitoring plants in freshwater systems. Specific methods should be tailored to the specific structure and water body under evaluation. Measuring submerged plant communities generally requires the use of scuba divers. Surveys may be qualitative or quantitative (Southard et al. 2006a); the former is used primarily to document changes to the plant habitat that may result from physical factors (e.g., storms) other than the measure of interest (e.g., light transmission). Qualitative surveys are usually short and can involve simple recording of visual observations of habitat conditions. They are often conducted during the times of relatively low plant growth (spring, fall, winter).

Quantitative surveys are usually conducted during the summer, at the general time of peak plant growth, but may be conducted at any time of the year, depending on the goals of the study. This type of sampling incorporates preset transects arranged in a pattern similar to that described for the fish sampling. The specific number and location of the transects will depend on the specific characteristics of the site under evaluation. Suitable reference transects need to be located away from the influence of the overwater structures, but sufficiently close to transects located at the structure to ensure that both experience similar environmental and biological conditions. Transect depth is an important consideration, because plant density may differ considerably over relatively short depth differences (R. Thom, personal communication, 2006). Sampling intensity along each transect should be standardized (Southard et al. 2006a). Data collected during the quantitative surveys include the following categories:

- Plant density (number of "shoots" per 0.25-square meter quadrat; at least three times per station) and percentage cover (visual estimate).
- Leaf length (eelgrass) or plant height (other macrophytes); measured to nearest centimeter at least three times per station.
- Visual estimate of epiphyte load (by defined categories, such as light, moderate, heavy).
- General observations of plant condition (e.g., shredded leaves, evidence of herbivory).

# Step 7: Develop experimental design and statistical analysis

The monitoring program should be organized in a way that provides study results (data) that are unbiased, applicable to other situations, and testable in statistical hypotheses. The proposed framework is designed to detect an effect resulting from the implementation of a conservation measure - if the conservation measure has a statistically significant effect on the monitored feature, then the measure will have been demonstrated to work.

An introduction to experimental design and statistical analysis is beyond the scope of this document, and many good books are available on these topics. The present document provides a generalized framework for organizing the experimental layout of an effectiveness monitoring study. Different situations, conservation measures, monitored species, or habitats, or different goals or applications for the results of the effectiveness monitoring experiments could require different approaches.

## STUDY DESIGN PRINCIPLES

The following are key elements of the experimental design and statistical analysis presented here:

### ANOVA

Analysis of variance (ANOVA) is used to determine whether the differences between observed responses are more different than would be dictated by chance alone. Typically, ANOVA is used to identify statistically significant differences in the responses due to different treatments, and it is proposed as the statistical test for the conservation measures addressed here (light penetration).

**Response Measurements**

Response measurements are the observations collected to characterize the system under study and the effectiveness of the conservative measure under study. These data will typically be field observations. In an ANOVA, these are the dependent variables, such as eelgrass density beneath a dock.

**Experimental Factors**
The elements of the study design that are directly manipulated or selected are termed experimental factors. In an ANOVA, these factors are sometimes called treatments and might include the absence or presence of grating in a dock as a factor controlling light beneath the dock.

### Covariates

Covariates are other factors that can influence the monitored response variable. For example, the response variable of eelgrass growth is partially controlled by temperature; different study areas can have different temperature regimes. Using a characterization of the temperature for different study sites (e.g., average annual temperature) as a covariate may improve the sensitivity of the experiment to the conservation measure treatment. The inclusion of such explanatory or independent variables in an ANOVA creates what is commonly called an analysis of covariance (ANCOVA). The collection of ancillary field data is always a good practice, and whether such information is included in the ANOVA or not, it could prove useful in interpreting the results of the effectiveness monitoring program.

## EXPERIMENTAL DESIGN

Because of the many sources of variability associated with physical, chemical, and biological parameters in living systems, a robust design that is simple and scalable to different situations will be most useful in a variety of experimental studies conducted for the purpose of determining effectiveness of conservation measures.

The experimental design recommended here is a before, after, control, impact (BACI) study design. In the BACI model, response measurements are made both before and after the conservation measure is instituted at a selected test location. By taking both observations at a single control and impact site, a direct comparison of results can be made that eliminates many sources of uncontrolled variability that could exist between two different study areas. To control for response differences that occur through time, independent of the implemented effectiveness measure, both control and impact study sites are included in this experimental design. Changes that occurred through time at the impact site, independent of the experimental manipulation, can be characterized by before and after measurements at the control site. The characteristics of the control study site should be very similar to those of the impact site, and it should be in close proximity. For example, eelgrass density is measured beneath a dock before and after installation of a grating; this is the impact study site. A portion of the same eelgrass bed that is nearby, but removed from the shading influence of the dock, could be monitored as the control study site. When control and impact study sites are paired in this way, the design is frequently termed a BACI paired (BACIP) study design.

### Recommended Experimental Effort

The basic framework of the BACI experimental design is as follows:

- Impact site(s), sampled before and after implementation of conservation measure.

- Control site(s), sampled before and after implementation of conservation measure.

Replication can be achieved through any of the following:

- Multiple observations in time, before and after institution of conservation measure, at a single pair of impact and control sites;
- Multiple impact and control sites; and
- Some combination of both of the above.

As requested by Washington DNR, three study designs for three levels of field effort were considered. Suggested experimental designs fitting those levels of effort are provided below, with comments on their feasibility. The three scenarios corresponding to the input from ESA Team staff are as follows:

- Minimum – a sampling effort that would provide a statistically sound study design.
- Expanded sampling effort that would add observations to either increase the statistical sensitivity of the study or include additional study parameters.
- Most expansive sampling program with virtually unlimited budget allowing increased statistical sensitivity and robustness as well as adding study parameters.

The field effort (number of observations) for each level of study design is summarized in Table 3-8 and discussed below.

**Table 3-8. Sampling effort required for different study design scenarios.**

| Study Design Elements | Field Effort (number of observations) | | |
|---|---|---|---|
| | **Minimum** | **Expanded** | **Unlimited** |
| Treatments | 1 | 1 | 3 |
| Ecosystems under study | 1 | 5 | 5 |
| Pre-implementation | 3 | 3 | 3 |
| Post-implementation | 3 | 3 | 6 |
| Replication | 1 | 1 | 3 |
| Total Observations | 6 | 30 | 405 |
| **Total Cost** | **$22,000** | **$110,000** | **$1,500,000** |

**Minimum Experiment**
As a minimum level of initial experimental effort, three replicates are recommended for each of the before and after, control and impact combinations for a single pair of control and impact sites, which are selected from a listing of active leases on state-owned aquatic lands in rivers, saltwater, and lake ecosystems in the geographical area of interest (see Appendices A and B for details of site selection). This recommendation is based on experience in field studies; with some data from first implementation of the monitoring program, the variability in the responses can be used to refine the experimental design to achieve a particular goal of precision or confidence in the experimental conclusions. The replication of monitoring at one pair of sites has the advantage of not requiring that additional sites be identified; this may have benefits in controlling costs associated with field monitoring efforts. It has the disadvantage of providing no information about differences between impact sites in response to conservation measures. It is the most feasible study design, in that it requires that only one site (for a BACIP design) or one pair of control and impact sites be manipulated experimentally.

By monitoring an experimentally manipulated site through time, the results could display trends of the monitored variables' response. The recommended statistical approach for this BACI design is a repeated measures ANOVA[2]. For example, eelgrass beds beneath a dock may experience more rapid growth shortly after a grating is installed in the dock. After a while, other factors (nutrients, temperature) could become limitations, and the increase in growth rate observed initially would ultimately diminish. Conversely, some time may be required before a conservation measure shows some effect. Therefore, an important part of the study design for any conservation measure is to determine the correct timing for measurement of the "after" condition. This choice will be different for different conservation measures.

As described in Step 1 of this chapter, we assumed for the purposes of this analysis that a total of $30,000 was available for the minimum level of experimental effort per conservation measure. Based on the recommended protocols identified in Step 6 of this chapter, we assume that a 3-person crew could sample a single site in a day. Including hourly wages, per diem, travel, mobilization and demobilization, the cost of sampling a single site is roughly $1,800. Thus, one replicate from a BACI design would cost approximately $7,200. Three replicates would cost approximately $21,600. Data reduction, analysis, and reporting could easily consume the remaining $8,400. However, $30,000 appears to be a reasonable budget for the level of effort proposed.

**Expanded Experimental Effort**
The BACI experimental design is scalable in numerous ways. Multiple pairs of control and impact study sites would allow the characterization of the effectiveness of the conservation measure across locations. The obvious advantage of this expansion is that it provides data on how well the conservation measure works in different places, and this is important for understanding how the results may be extrapolated to sites across the state.

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[2] The simplest BACI design, where a single observation is collected before and after the impact, is considered a repeated measures design, because the before and after observations are made at the same location at different times. The experimental design described above is just an extension.

The recommended expansion at this level of field effort is to apply the same design described above in each of five different ecosystems or habitats: nearshore saltwater habitat, oligotrophic, mesotrophic, and eutrophic lacustrine habitats, and riverine habitat.

The additional constraint imposed by this expanded design is that one site or one pair of sites is identified in each ecosystem. This requires that similar conditions (e.g., dock structure) be available for each of the identified ecosystems.

If it is assumed that logistical factors such as travel time, level of effort, labor costs, for example, remain equal across the ecosystems, the total cost associated with the expanded level of effort would be approximately $110,000.

**Unconstrained Experimental Effort**

Additional manipulated factors may also be included in the study design; for example, different treatments may be applied to different control-impact site pairs to compare their effectiveness. The difference in effectiveness between the measures can then be compared in the ANOVA. More sites can be included in each combination of ecosystem, conservation measure, and site condition.

As an example of the experimental design possible with an unconstrained budget, three different implementation methods for a conservation measure would be included (e.g., lights beneath dock, gratings, or prisms). To include replication for each combination of factors, three sites would be monitored in this example. To track changes over a longer period of time in each habitat and for each implementation method, six observations would be collected in the period after implementation in both the control and impact sites.

This level of field effort is substantially more expensive, and perhaps prohibitively so. For this example, the number of field observations would be more than 60 times greater than that in the minimum design. The associated costs may increase in direct proportion with number of observations, because of differences in travel time, mobilization and demobilization costs, number of sets of monitoring equipment, among other factors, but they would be dramatically greater. Another consideration of the feasibility of this level of effort is that it requires sites for each combination of implementation method and habitat. These sites must have associated activities that make them suitably representative of other sites, and they must be amenable to the modification(s) required for the conservation measure. With these constraints on eligibility, the population of available sites may be so limited as to make the field execution of this design impractical.

Unlike the expanded effort sampling scenario, it is difficult to estimate the approximate costs of this level of effort with any certainty; therefore, no estimate is provided here.

### Application of the Monitoring Program Design

Extrapolation of monitoring program results to the remainder of sites with the activity category requires that the sites selected for the effectiveness monitoring program be representative of the population of all sites of interest. For this reason, an important component of any monitoring program design is the identification of the key features of the sites and their activities, relative to the Covered Species, conservation measures, and habitats.

Any of the experimental study designs discussed herein could be applied to monitoring multiple responses (e.g., eelgrass productivity and fish movement) at any given location and time. This approach might allow for economy in the field study while providing information about a variety of responses to a given conservation measure. The approach would only require that separate ANOVAs[3] be conducted for the data from each response variable.

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[3] The ANOVAs would be equivalent if the experiment design were equivalent in layout and replication. Otherwise, different analytical approaches would be required.

# 4. Implementation

## Step 1: Preliminary study plan

Before initiating an effectiveness monitoring program for a conservation measure, it is useful to develop a preliminary study plan, which guides all subsequent steps of the monitoring program. A preliminary study plan presents the purposes or objectives and outlines an initial design, including a list of candidate sites and proposed monitoring parameters. An important facet of the plan is the provision for a reconnaissance survey of the candidate sites and a review of the proposed methods. This survey can increase the efficiency and relevance of the study by eliminating sites that are not feasible to monitor or parameters that cannot be measured effectively. This information can then be used to finalize the study plan. Appendix A provides an example of a study plan developed to evaluate the conservation measure to increase light under overwater structures.

The most important step in the development of a study is to clearly and concisely define the question (Green 1979, Noss and Cooperrider 1994) in a manner understandable to all involved, from the project field crew to the managers of the facilities included in the study, to the general public. The question should be framed to answer the ultimate goal or purpose of the conservation measure as it relates to Covered Species. Often, the ultimate goal is not contained within the wording of the measure, which more typically states the practical, but proximate, goal. For example, the conservation measure selected as the test case presented here is stated as follows:

> "Incorporate measures that increase the ambient light transmission under piers and docks. These measures include, but are not limited to, maximizing the height of the structure and minimizing the width of the structure to decrease shade footprint (replacement maintenance); grated decking material."

This wording simply and clearly defines the practical action of the measure, and guides the effectiveness monitoring program to focus on measurement of light under the structure. However, the underlying goal, which is to reduce potential impacts to Covered Species – in this case, to reduce impediment to fish migration—is not directly stated. If the rational for increasing light under structures is not understood, the monitoring program could simply focus on effectiveness monitoring consisting of light measurement under the structure, rather than including the context of other factors important to fish migration.

Following a series of logical steps, which are outlined in the preliminary study plan, leads to the development of an appropriate and complete study to monitor the effectiveness of conservation measures. Typically, the first step is a literature search to obtain necessary background information on the interaction between the Covered Species and the issues addressed. The second is the development of a conceptual model to understand the factors that affect the Covered Species and the role of the issues to be addressed in the study. From this basis, an appropriate set of issues and effects can be recognized, and accordingly, the relevant parameters and methods to measure them can be identified.

The literature search should focus on the general factors that affect the Covered Species in question and should provide information on the specific issues addressed by the measure. Although it is often advisable to consult with a reference librarian while planning and conducting a literature search, there are many web-based or subscription sources available to the individual researcher. The following list recommends several that offer the capability to download selected citations directly into a bibliographic database.

- ISI Web of Science (http://portal.isiknowledge.com/portal.cgi) - Web of Science (science edition), the online equivalent to Science Citation Index, provides access to bibliographic information gathered from thousands of scholarly journals. This is one of the primary sources of scientific publications and was the main database used for this project. It is available by subscription.

- BIOSIS (http://portal.isiknowledge.com/portal.cgi/biosis) - BIOSIS is one of the ISS Web of Knowledge databases and provides worldwide comprehensive coverage of research literature in the biological and biomedical sciences from 1969 to present. Subject areas include cell biology, experimental medicine, microbiology, radiation biology, veterinary science, zoology, among others.

- Cambridge Scientific Abstracts (CSA) (http://www-md1.csa.com/) - CSA provides access to the following:

- Aquatic Sciences and Fisheries Abstracts (ASFA) - derives information from an international network of information centers monitoring over 5,000 journals, books, reports, conference proceedings, translations and limited distribution literature.

- Oceanic Abstracts (OA) - focuses on worldwide technical literature pertaining to the marine and brackish-water environments. Topics include marine biology, physical oceanography, fisheries, aquaculture, meteorology, and geology.

- Pollution Abstracts (PA) - a leading resource for environmentally related literature addressing pollution, its sources, and control.

- Water Resources Abstracts (WRA) - provides summaries of the world's technical and scientific literature on water-related topics covering the characteristics, conservation, control, pollution, treatment, use and management of water resources.

- National Technical Information Service (NTIS) (http://www.ntis.gov/ ) - The NTIS Database is a resource for accessing US government-sponsored research and worldwide scientific, technical, engineering, and business-related information. NTIS is the largest central resource for government-funded scientific, technical, engineering, and business related information available today, with information on more than 600,000 information products covering more than 350 subject areas from at least 200 federal agencies.

- Google/Google Scholar (http://www.google.com; http://scholar.google.com) - Google is a general web search engine that is often useful for very quick searches. Google is often a good source for unpublished papers (gray literature). Its main disadvantage is that there are often many irrelevant links that must be negotiated in the search for appropriate ones. Google Scholar is a simple way to search for scholarly literature across many disciplines and sources: peer-reviewed papers, theses, books, abstracts and articles, from academic publishers, professional societies, preprint repositories, universities, and other scholarly organizations. Google Scholar helps identify the most relevant research by sorting articles the way researchers do, weighing the full text of each article, the author, the publication in which the article appears, and how often the piece has been cited in other scholarly literature. The most relevant results appear on the first page.

The literature review provides the information necessary to build a conceptual understanding of the issues relevant to the conservation measure. It may also identify key researchers in the field who could be consulted to provide additional insights. The review may also reveal a highly relevant document related to the issue that includes a conceptual model that could be modified to meet the needs of the effectiveness monitoring, as was the case in the present study of the effects of light reduction under overwater structures.

A conceptual model describes current knowledge about the essential features of ecological phenomena, identifies the principal processes taking place, describes interactions among components, and identifies knowledge gaps (Heemskerk 2003, Simenstad et al. 2006). A conceptual model is frequently prepared as a diagram that shows several variables and indicates the relationships among them (Jackson et al. 2000, Heemskerk 2003). This provides a clear, concise visual statement of the concepts associated with the measure, which can be useful in communicating the issues across disciplines, and to all groups involved (Heemskerk 2003). The conceptual model should be simple enough to be useful in organizing thoughts about an issue, yet should include sufficient detail to adequately describe the relevant ecological structure and processes involved (Jackson et al. 2000).

The literature review and the understanding gained from building the conceptual model lead to the development of parameters that should be possible to measure. In assembling a list of possible parameters, it is useful to identify those that are ancillary, which do not directly evaluate the measure but which may help explain the results, and those that are of primary importance in the process. Ancillary parameters could include the characteristics of the site or facility and several physical features of the environment. For example, the evaluation of the light under overwater structures measure included several descriptive features of the structures and several light and water quality characteristics (Chapter 3, Tables 3-6 and 3-7). It is useful to list the justification for considering each parameter, the methods by which each could be measured, and constraints or limitations in measuring each parameter. The various biological parameters also can be ranked as primary or secondary in importance (Chapter 3, Table 3-8). For example, parameters of primary importance in evaluating a conservation measure could involve various characteristics of the targeted Covered Species, including those associated with important habitat features and those directly related to aspects of the species' biology. From the parameter matrix, the most effective parameters can be selected for evaluation of the conservation measure.

Following parameter selection, the preliminary study design should focus on experimental and statistical features in consultation with an environmental statistician.

The proposed design should be outlined in sufficient detail to guide a field crew, but should also retain flexibility for future adjustment based on the reconnaissance visit and pilot study outlined in Steps 2 and 3 below. The plan should also include the initial design for the study data sheets. The preliminary study plan will likely list more study sites and parameters than will ultimately be incorporated in to the final work plan for the evaluation of a conservation measure. The site reconnaissance may result in the rejection of candidate sites for several reasons: for example, there is no reasonable opportunity for the measure to be applied, the site may not be safely accessible, or the characteristics of the structure may limit the accurate definition of the effects of the measure (Appendix B).

## Step 2: Site reconnaissance

Prior to conducting a pilot study, it is advisable to conduct an initial site reconnaissance to evaluate and determine critical information about the potential study sites. The initial set of potential monitoring sites for the present study was accomplished by examining a list of active leases on state-owned aquatic lands in rivers, saltwater, and lake ecosystems (see Appendices A and B for details). Several questions guided the evaluation of potential monitoring sites to reduce the overall list to those most feasible to monitor (modified from Appendix A):

- Has the specified conservation measure been implemented at the site? If not, is the measure scheduled to be implemented in the foreseeable future? Will implementing the measure make a difference?
- How accessible is the site? Are there any special accessibility requirements?
- Can permission to examine the site be gained from the facility operator or other responsible party?
- Is the site representative of the larger body of leases where conservation measures may be implemented?
- What are the physical conditions of the facility and the site that may affect the conduct of the study?
- Are there operational or structural concerns that may affect field personnel safety?

- Can the necessary habitat observations and measurements be taken efficiently and accurately at the site?
- Can field personnel conduct a preliminary reconnaissance or assessment within a reasonable amount of time and within the established schedule?

The information gained from this preliminary evaluation can be used to further refine the list of candidate sites, which is then evaluated in more detail by a relatively short site-reconnaissance visit. If it is necessary to determine the street address or other location identifier of the facility prior to the visit, online maps and aerial photographs can be useful, and further, can enable the preparation of site-specific drawings as needed.

This reconnaissance visit must involve the field crew leader and other critical personnel, but does not need to involve the entire field crew. During this visit, the information gained during the preliminary evaluation can be verified and corrected if necessary. Importantly, the reconnaissance visit affords the field crew leader the opportunity to discuss the monitoring study with the owner, facility manager, or other responsible party, and to learn about security provisions and operations of the facility. This coordination step is important to assure the lease-holder that the study will be conducted in a manner that does not interfere with operation of the facility. The field crew leader can directly assess potential safety concerns and discuss with site management possible alternatives that could ameliorate them.

The site-reconnaissance visit, which should include photo documentation if permitted, can provide the following information (modified from Appendix A), which will be useful in the selection of final study sites:

- The location of the target facility and its geographic (global positioning system) coordinates;
- The best access to the site, whether over land or by water;
- The configuration of the site as it relates to the conduct of the monitoring study;
- The optimum locations for environmental sampling within the facility;
- The general shoreline and seabed characteristics, in consideration of selecting appropriate equipment for use at the site; and
- The characteristics of adjacent properties that may affect the monitoring study or the implementation of the conservation measure.

These steps should be followed whether or not the site visit is conducted before the pilot study or the full evaluation study. It may not be possible to conduct a pilot study at every site at which a conservation measure is to be evaluated. It may be unnecessary to use any of the planned sampling methods during the site visit; however, site-specific conditions that could affect the methods should be noted. Results of reconnaissance visits contribute to selection of the final list of sites that can be monitored most efficiently and safely to meet the needs of the evaluation program. Examples of the types of information that can be gathered during the site visit are described in Appendix A.

## Step 3: Pilot field study

A pilot field study is a small-scale model of the full study that is being planned. A report of the pilot study conducted to evaluate the measure to increase light under overwater structures is included as Appendix B. It is conducted over much shorter temporal and spatial scales than those planned for the full study. Green (1979) stressed the importance of a pilot study, saying that there is "no substitute for it."

A pilot study generally serves two main purposes: the first is related to statistical and design questions, and the second to the issues of implementation in the field. Frequently, there will not be sufficient historical information available to allow the complete design of a full study. A pilot study can provide the necessary information about the variability of the system of interest to allow design issues such as the number of samples needed for desired estimates of precision, the sampling frequency and locations required to address the issue being studied, and whether or not the sampling techniques have bias that may affect the interpretation of the results (Green 1979, Lancaster et al. 2004). The pilot study will allow the adequacy of the sampling approach to be evaluated, including whether or not the sampling device will collect the appropriate information about the target population. Green (1979) pointed out that all sampling devices and protocols have bias, but that understanding the bias can reduce its potential impacts to a study. Results from the pilot study can be included in the final evaluation of the full study. However, one cannot simply add the pilot data to that of the final study (Green 1979), but rather, one must apply appropriate statistical techniques (Cochran 1963).

The second main purpose of a pilot study is the practical testing and identification methods that work at the site(s), and elimination of those that do not. Pilot-scale study can provide the field crew experience with new or unfamiliar methods, and allow correction of anticipated problems in their application before the full study begins.

A pilot study can address other potential issues that could interfere with a full study. Key among these are as follows (adapted from Green 1979, Simon 2006):

- Is the sampling adequately directed at the target population?
- Are important parts of the target population left out because of the survey timing or sampling techniques?
- Does the survey take much longer than anticipated?
- Are protocols clearly written and easy to follow?
- How well does the equipment function under all field conditions? What can be done if it fails? Are back-up systems available?
- Can electronic data be read by the computer system running analyses? Do they supply all of the correct documentation required for study?

- Are the data sheets adequate and efficient? Is data entry cumbersome because too much irrelevant information is being recorded or the data sheets are poorly organized?
- Are any important data left out?

Although there is no need to fully justify the sampling extent, frequency, or number of samples to be collected, the pilot study should be conducted over the range of sampling conditions included in entire study and should include a well-defined statement of objectives (Lancaster et al. 2004). Thus, the intensity of the pilot study depends on the complexity of the full study, including the numbers of habitats that will be sampled and any other conditions likely to be encountered.

Arguments against investing in a pilot study were listed by Green (1979): lack of time, resources (including funding), and confidence that a pilot study can generate data that can be used in conjunction with a full study. Green's (1979) response to the arguments was that omission of a pilot study may waste valuable time and resources by failure to pretest aspects of the full study that are new or complex or that will involve a coordinated team approach. The pilot study allows the full team to become familiar with the study goals and sampling procedures.

## Step 4: Implementation

Before implementation of the conservation measure monitoring, the preliminary survey plan must be transformed into a final work plan that allows different field crews to collect data in a consistent and comparable way across all sites and times (Noss and Cooperrider 1994). The plan should include contingencies to help the field crews adjust when things do not go as planned. One simple contingency is to include contact information for key staff involved in the planning and design of the study.

Probably the key question in implementing the effectiveness monitoring program concerns the most appropriate timing of the monitoring activity before and after installation of the conservation measure. Generally, the conceptual model and the information used to develop it should guide the timing of conservation measure monitoring.

The initiation of before-installation condition monitoring generally should be as close as possible to the time of the implementation of the measure, but it must be conducted at an ecologically relevant time. The conceptual model could possibly indicate that there is a need for several monitoring events required to establish an accurate picture of the before-installation condition.

Consider, for example, the measure to increase light under overwater structures. The primary effect established in the conceptual model and literature review was the interruption of juvenile salmon migration. Although the model defined the typical season within which the migration is most likely to occur, there is sufficient variability in the process to warrant monitoring at various time periods within the migration season. It could even be advisable to sample across more than one migration season to more precisely define the before-installation condition.  The monitoring results must be understood in the context of observation of biological effects related to light limitation (Table 3-7) and other (physical, chemical, etc.) effects that are recorded.

The change in light transmission beneath the overwater structure can be measured as soon as construction has been completed to determine whether or not there was an increase in light under the structure after installation of the conservation measure. However, it could require several surveys within a migration season and possibly over several seasons to document a potential improvement to salmon migration at the study site related to the conservation measure. The literature review and conceptual model would have indicated whether or not a delayed response by juvenile salmon was to be expected.  Based on the literature in this case, it is expected that juvenile salmon would respond fairly rapidly to a change in light transmission, allowing monitoring to begin within the first migration period after the measure were implemented.  In other cases, systems may respond at a different rate, and monitoring should therefore be adjusted on a case-by-case basis in development of a site-specific study plan.

## Step 5:  Analysis, interpretation, management

The duration of monitoring after a conservation measure has been implemented is projected in the planning stages, but can then be modified in the course of monitoring based on several key considerations: Is the response statistically significant and consistent?  If so, does the same, or similar, response occur over the range of conditions under which the measure may be applied?  The duration of monitoring is a balance between the minimum number of surveys required to determine that a measure has been effective, and a maximum number beyond which little new and valuable information is gained.

If the early post-implementation surveys indicated that the measure was not effective, it should not necessarily be immediately abandoned.  Instead, the study design and implementation should be first evaluated.  A review could address correspondence of study design to the system specification described in the conceptual model; consistency of study implementation and conformance to protocols; and similarity of control versus test-site results. Various environmental factors that should be reflected at the control sites could have changed over time, with corresponding effects to the interpretation of monitoring study results, particularly if the response time of the system under examination is relatively long (Gregory et al. 2006).  Review of the ancillary data collected could help to determine whether there could have been larger-scale, regional factors affecting the results.   It also could be that the measure did not cause sufficient change in the environment to yield the expected response from the targeted species.  In the context of the present monitoring program, this is difficult to evaluate, because to do so would require an experiment involving the implementation of a gradient of light transmission levels, rather than of a single level as a conservation measure.

Following the suggested review, a determination of the conservation measure's effectiveness should be made. If the measure was effective, the conservation measure evaluation matrix described in Section 2 can be updated, and the evaluation process can continue by addressing other conservation measures. If the measure was not effective for reasons not linked to larger-scale environmental changes or issues with the study design and implementation, then the conceptual understanding of the issue should be re-examined to determine whether or not the measure was appropriate initially or whether alternative approaches should be considered.

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# 6. Appendices

# Appendix A – Work Plan Design

## A-1 Introduction

Chapter 3 of this document described a stepwise process for identifying potential monitoring parameters, selecting monitoring protocols, and developing experimental designs for individual conservation measures. This appendix describes elements that must be considered in the transition from monitoring program design to field implementation and illustrates key decision points as they relate to conservation measures designed to increase light transmission. Experiences associated with the Pilot Field Study (Appendix B) provided the foundation upon which this appendix was crafted.

## A-2 Recommended work plan elements

### A-2.1 Goals and Objectives

The goals and objectives of a monitoring plan will be determined by the ways in which an activity is thought to impact species of concern. It is important that the reasons for monitoring can be clearly stated to choose appropriate monitoring parameters and data collection methods, and to provide field investigators with the requirements of the investigation.

For the light transmission study addressed here, the goal is to improve conditions for certain species by increasing light under overwater structures. The objectives of the study are to determine which conservation measures contribute the most to increasing light transmission, and how those increases might vary among different sites.

### A-2.2 Preliminary Monitoring Site Selection

A subset of leases should be selected from the NaturE database for initial consideration as prospective monitoring sites. Locations and general lease configurations can be determined using topographic maps, a geographic information system (GIS), or internet mapping sites. The following should be considered in the selection of potential monitoring sites:

- Has or will the lessee implement specified conservation methods?
- Does the site have the correct elements to meet the goals and objectives of the effectiveness monitoring program?
- Is the site and all of its components easily accessible by small boat and/or automobile?

- Is permission to examine the site easily attainable from the lessee or other responsible party?
- Is the facility representative of a defined activity group (e.g., overwater structures)?
- What are the known physical conditions of the facility and the site?
- Can field personnel safely, efficiently, and accurately make observations and measurements at the site?
- Can field personnel conduct a reconnaissance and/or assessment within a reasonable amount of time and within the established schedule?

The product of the preliminary selection process is a list of sites for initial reconnaissance. The result of this selection process for light transmission is provided in the pilot field study (Appendix B).

## A-2.3 Monitored Parameters and Variables

The parameters and variables for use in monitoring of light transmission and the reasons for their selection were described in Chapter 3. They are listed here with a summary rationale for their inclusion.

### GENERAL SITE CHARACTERISTICS

General site characteristics (Table A-1) will be useful for the interpretation of the collected biological and physical data. In addition to the parameters listed below, extensive color photographs should be taken to record the site characteristics.

**Table A-1. General site information to be recorded during site reconnaissance and assessment.**

| | Parameter | Reason | Method |
|---|---|---|---|
| General | Calendar date | Season determines angle of sun, which affects light transmission; fish migration | Visual observation |
| | Time of day | Determines angle of sun, which affects light transmission; may affect fish migration or other behavior | Visual observation |
| | Location (street address, geographic coordinates) | Reporting, future reference for visits, relation to Washington DNR data base | Maps and GPS receivers |
| | Field crew members | QA/QC and future reference | |
| Weather | Cloud cover (type, percentage) | Affects available light intensity | Visual observation |
| | Rainfall | Affects available light intensity and ability to observe fish | Visual observation (descriptive) |
| | Wind direction, approximate speed | Affects surface chop (direction, size) | Visual observation (descriptive) |

| | Parameter | Reason | Method |
|---|---|---|---|
| | Water surface conditions | Affect visibility from above surface; may affect light transmission underwater | Visual observation (descriptive) |
| Structural | Activity (type, frequency) | Affects fish activity, plant habitat, field crew safety | Visual observation, Washington DNR management data |
| | Length, width, height, construction material | Affect degree of shading under structure | Visual observation (categories, direct measurements), permit information |
| | Pilings (spacing, type) | Affect degree of shading under structure | Visual observation |
| | Ancillary structures (walkways, skirting) | Affect degree of shading under structure | Visual observation; permit information |
| | Orientation (north-south, east-west) | Affects available light under overwater structure | Visual observation |
| | Conservation Measures - light transmission devices (number, type, size, location) | Affect light transmission under overwater structure | Visual observation; permit information |
| Other | Substrate composition | May affect type of plant that can live under specific overwater structure | Visual observation |
| | Wave/stream energy | May affect type of flora and fauna that can live under specific overwater structure | Visual observation |
| | Tidal elevation, lake/river stage | May affect light under overwater structure (e.g., high tide "reduces" effective height of dock, reducing light) | Published records; USGS flow records |
| | Adjacent land use | May affect biological and physical parameters including wave exposure, light, and accessibility by fauna | Maps, direct observation, Washington DNR data base |
| | Shoreline shading (vegetation, hill slope, buildings) | May confound (i.e., exacerbate) effects of overwater structure | Visual observation |

## LIGHT AND WATER QUALITY CHARACTERISTICS

Light is the primary physical parameter that will be measured, because these data are required for evaluation of any light conservation measures (Table A-2). Light may be measured in two ways:

- Irradiance – photosynthetically active radiation (PAR), in the waveband (400 to 700 nanometer wavelength) necessary for plant photosynthesis; it is measured as micromoles of photons per square meter per second ($\mu mol/m^2/s$).

- Illumination – available for fishes' (and other animals') vision; it is measured as lux, the number of lumens that strike one square meter of surface.

Water quality characteristics that may be affected by facilities or activities within the lease must also be measured. These would include, at a minimum, those listed in Table A-2, especially turbidity.

**Table A-2. Potential physical parameters.**

| | Parameter | Reason | Method |
|---|---|---|---|
| Light | Irradiance (PAR) | Demonstrates whether or not measure has increased light under overwater structure; direct effect on plants | Spherical quantum light meter |
| Light | Illumination (lux) | Demonstrates whether or not measure has increased light under overwater structure; light available for fish vision | Photometric light meter |
| Water | Temperature | Affects plant growth | Thermometer; CTD[a]; YSI Sonde or similar in situ device |
| Water | Salinity (marine, estuarine) | Affects plant growth | YSI Sonde, refractometer, or similar in situ device |
| Water | Alkalinity, hardness, pH, conductivity (freshwater) | Affects plant growth | YSI Sonde or similar in situ device; water sample collection, commercial kits |
| Water | Clarity | Affects light transmission; affects salmon migration (particularly in freshwater systems) | Secchi disc; horizontal black disc (fast-moving waters, Davies-Colley 1988); nephlometer; suspended solids |
| Water | Turbidity | Affects light transmission; affects salmon migration (particularly in freshwater systems) | Turbidimeter |
| Water | Water depth | Plant distribution changes with small-scale depth changes; affects light transmission | Echosounder; depth gauge; leaded, marked line |

a - CTD Conductivity, temperature, depth (salinity measurement) device.

## BIOLOGICAL CHARACTERISTICS

Reduced plant production and altered faunal behavior (e.g., use or avoidance) are the two primary biological effects targeted by conservation measures for light transmission. The primary concern is the effect of reduced light directly on juvenile salmonids, but other recreationally, commercially, and ecologically important species are affected by available light. These include crabs, forage fish, bivalve shellfish, and submerged aquatic vegetation.

Juvenile salmonids are of primary interest in the monitoring described in this plan. Surveys should collect information on their presence and behavior, as well as the presence of related species, including the following:

- Fish and invertebrate species composition (if possible) and abundance (direct counts or by defined category).
- Approximate fish length (2.5-centimeter categories).
- Approximate location in water column.
- Fish and mobile invertebrate behavior (e.g., feeding, active swimming, predator avoidance, shadow avoidance).
- Salmonid location in relation to the structure and/or shadow footprint (e.g., under, within 10 meters, farther than 10 meters of the target structure).
- Presence/absence and relative abundance of submerged aquatic vegetation (SAV).
- Associated finfish and invertebrate species.

This information will be collected by snorkeling or surface observation, depending on conditions.

# A-3 Field methods and protocols

## A-3.1 General Procedures

The pilot field study (Appendix B) demonstrated the need for well-defined field methods and protocols. Key methods are the following:

- Obtain accurate facility locations (e.g., street addresses and/or geographic coordinates).
- Create drawings of target structures or facilities from available aerial photos (e.g., Google Earth).
- Indicate on the drawings where observations will be made and what data will be collected.
- Create and follow a checklist for obtaining data.
- Assign clear and specific roles and duties for data collection to field team members.

It is important for purposes of statistical analysis and comparability over time to establish transects and/or sampling points. However, implementation of the sampling design should be conducted in such a way as to minimize the effect of the observer on site conditions, fish, invertebrates, and submerged vegetation that may be associated with the structure or at the reference sites.

## A-3.2 Biological and Physical Observations

Monitoring of juvenile salmon and other fauna and flora in the vicinity of site structures can be done by observers snorkeling or on shore wearing polarized sunglasses. Shore-based observations will be generally limited to gross observations, such as the presence of and relative size of a school of more common species (e.g., chum, forage fish, perch).

Light and water quality measurements can be taken at locations determined by the specific structure design and orientation, and should include ambient (above the water) and in water measures. General guidelines for measuring light levels are as follows:

- Off the south or west side of the structure - ambient lighting conditions, in water measures, just above the substrate.
- Under the structure on the north or east side - ambient lighting conditions, in water measures, just above the substrate.

Vertical measurements should be taken at specified intervals (e.g., 1 meter) until both irradiance and illumination readings reach zero.

Horizontal transects for biological, light, and water quality observations should ideally include one underneath the structure, one adjacent, and one that begins about 30 meters away from the structure and continues in a direction away from the structure. The actual lengths of transects will depend on the size of the structure being evaluated. Snorkel surveys require relatively good underwater visibility (e.g., Secchi disc readings should be >2.5 meters). Measures along the transect should be taken at specified intervals of approximately 2 meters near (<10 meters) and under the structure, but can be as far as 10 meters apart when measured away (>10 meters) from the structure.

## A-3.3 Timing

### MONITORING AND CONSERVATION MEASURE IMPLEMENTATION

The first chronological decision is when to begin monitoring after implementation of conservation measures. Initiation of monitoring may depend on the reason for monitoring, the species of interest, or habitat type. If the species of interest for increasing light penetration is salmon, monitoring should begin in the next season when salmonids, adult or juvenile, are expected to use the site. However, if the intent of the conservation measure is to improve habitat or the quantity of submerged vegetation, then one or more growing seasons may be necessary for the habitat to respond to the measure. The length of this delay must be weighed against the effects of other factors that may influence the effect of the conservation measure on the habitat.

Although the study design includes documentation of baseline conditions, as well as of control sites, monitoring probably should not be delayed longer than 3 to 5 years after implementation of the measure.

### SEASON

Season is a highly important determinant in the occurrence and behavior of all the organisms that will be targets of a monitoring program. For example, listed juvenile salmonids would not likely be found in nearshore marine or estuarine habitats in the fall. In addition, adult salmonids would likely be present in rivers leading to spawning grounds at this time. Crabs may migrate onshore in the spring for reproduction and offshore in the winter.

Thus, a critical consideration in the design of a monitoring program is the timing of observations at any particular site. This decision must be made according to the ecosystem (e.g., marine, estuarine, river, lake), associated habitats (e.g., submerged vegetation beds, high energy rivers, enclosed bays), and species.

### WEATHER, TIDE, FLOW, AND OTHER FACTORS

Critical factors that should be recorded include weather; tides, flow, or lake and river water level, and position of the sun, all of which contribute to the occurrence and behavior of organisms and the ability of observers to record the metrics associated with the organisms and sites. To allow comparison of data across time, it is also important that observations be made under similar conditions (e.g., season, tidal height, weather). Consideration of these factors may be specific to the ecosystem, habitat, site, and species under study.

# A-4 Field data recording

Standardized data forms should be provided to field teams. The forms should specify the data dictionary of the study (measures and observations to be taken), and measurement intervals, and should include space for recording information unique to the site or sampling event. For the present study, the data dictionary could include the following:

## A-4.1 General Information

- Calendar date
- Time of day (on and depart site and when measurements and observations are taken)
- Field crew members
- Location (street address, geographic coordinates)

## A-4.2 Weather Conditions

- Cloud cover (type, percent)
- Rainfall
- Wind direction, approximate speed
- Water surface conditions

## A-4.3 Structure Characteristics

- Activity (type, frequency)
- Orientation (north-south, east-west
- Pilings (spacing, type)
- Length, width, height, construction material
- Ancillary structures (walkways, skirting)
- Conservation measures - light transmission devices (number, type, size, location)

## A-4.4 Other Environmental Information

- Substrate composition
- Wave/stream energy
- Tidal elevation, lake/river stage
- Adjacent land use
- Shoreline shading (vegetation, hill slope, buildings)

## A-4.5 Light (on transects noted in field maps)

- Time of day that the measurement is taken
- Illumination (lux) ): Above water at surface, 1 meter depth, 1 meter above bottom
- Irradiance (PAR): Above water at surface, 1 meter depth, 1 meter above bottom (i.e., at the level where submerged aquatic vegetation uses the transmitted light)

## A-4.6 Water Conditions

- Temperature
- Salinity (marine, estuarine)
- Alkalinity, hardness, pH, conductivity (freshwater)
- Clarity
- Turbidity
- Water depth

## A-4.7 Biological Information

- Fish and invertebrate species composition (if possible) and abundance (direct counts or by defined category)
- Fish and mobile invertebrate behavior (e.g., feeding, active swimming, predator avoidance, shadow avoidance)
- Approximate location in water column
- Approximate fish length (2.5-centimeter categories)
- Associated finfish and invertebrate species
- Presence/absence and relative abundance of submerged aquatic vegetation
- Salmonid location in relation to the overwater structure (e.g., under, within 10 meters, farther than 10 meters of the overwater structure)

These data types are reflected in the preliminary data forms used in the pilot field study.

Because of the diversity and volume of data and information that is proposed for collection at each site, it could be easy to overlook a particular parameter or variable without a systematic approach to completing the record for each site. Thus, a data form that appears to be adequate and easy to use in the field must be tested under field conditions.

# A-5 Initial field reconnaissance

A field reconnaissance visit of potential study sites is recommended to determine the following:

- The actual location of the target facility and acquire geographic coordinates.
- The best access to the site whether over land or by water.
- Any special needs for access including security provisions, facility schedules, points of contact, etc.
- Whether any health and safety factors may limit field crew activities on the site.
- The configuration of the site.
- Locations for environmental sampling within the facility.
- General shoreline and seabed characteristics (to ensure that the appropriate monitoring equipment is selected).
- The nature of adjacent properties.

Results of the reconnaissance will help to determine which sites were the most practical to assess and will also supply the best information for the pilot study.

Site reconnaissance is intended as a cost-effective and relatively limited effort to ascertain the suitability of a site for study. Locations should be determined first by street address and documented using a global positioning system (GPS) receiver. Access can be either from land or by boat, and digital color photos should be taken to use for planning the final site assessment. Snorkeling or other in- or underwater examinations are not necessary during the reconnaissance.

The information acquired during the reconnaissance should be used to finalize the selection of parameters and variables to be measured, and to construct the final assessment data form and dictionary. In addition, the acquired reconnaissance information will ensure an efficient and cost effective site assessment and acquisition of the most meaningful data.

# A-6 Site monitoring

The execution of the site monitoring plan is described below.

## A-6.1 Monitoring Site Selection

During the reconnaissance phase, sites will be selected for continued additional detailed investigation or monitoring. Some of the factors to be evaluated in this selection are as follows, considering whether or not the sites fit certain descriptors:

- Conservation measures for the specific factor (i.e., light) are in place and functional.
- Conservation measures for other factors (e.g., creosote or wave impact reduction) are present.
- The site configuration or use precludes implementation of specific conservation measures (e.g., no access ramps for grating, industrial use).
- Level of use (boat, vehicle, or pedestrian traffic) will allow observations.
- Structure(s) are not too large and complex to clearly define effects.
- Structure construction is conducive to observations around and under.
- Access to the shoreline and critical structures relatively easy and direct.
- Shaded areas clearly defined.
- Access to affected areas safe and practical.
- Representative of a facility, ecosystem, or habitat type.
- Observations, especially snorkel surveys, can be made without legal or environmental problems (i.e., permission to enter the site can be obtained, private owners allow swimmers around boats).

## A-6.2 Implementation of Monitoring Plan

During the pilot field study, ENTRIX and Washington Department of Natural Resources (Washington DNR) personnel encountered a number of factors and situations that could influence the ongoing monitoring methods and/or locations for monitoring. They are noted below and discussed in the pilot field summary report (Appendix B).

### DATA USE AND APPLICABILITY

Water quality and light data collected in the monitoring study may not be useful for comparison between sites and ecosystems.

## TRAFFIC

Pacific Northwest urban traffic is infamous for its volume and congestion. Substantial delays can be caused accidents and normally slow traffic on Interstate and tributary roads.

## WEATHER

Weather can cause delays in the form of traffic congestion; it can create hazardous situations and influence monitoring conditions (e.g., behavior of organisms). Wind and other factors can develop relatively quickly; if staff members are not prepared, it could result in a hazardous situation.

## VESSEL OR VEHICLE BREAKDOWN

Mechanical failures of vessel or vehicle engines or other systems can cause unplanned delays that interfere with optimum data collection schedules.

# Appendix B – Pilot Field Summary Report

## B-1 Introduction

Appendix B presents the results of a pilot field study that was conducted to test and elucidate methods and procedures for monitoring conservation measures designed to increase the transmission of light through overwater structures. The field study included the following:

- Selection of initial sampling locations.
- An initial field reconnaissance.
- Selection of parameters and variables for monitoring.
- Selection of field methods and protocols.
- Development and testing field data sheets and dictionaries.
- Assessment of selected sites and evaluation of methods and procedures.

## B-2 Methods

### B-2.1 Site Selection

#### LEASEHOLD SELECTION

The sites selected for the pilot field study were examined in two phases - first, Washington Department of Natural Resources (Washington DNR) and ENTRIX personnel selected a number of sites for consideration as in the pilot study in riverine, saltwater, and lake ecosystems from NaturE, Washington DNR's financial management database. For practical reasons, the selection was restricted to the metropolitan Seattle area, with general location and site configuration determined using the mapping internet site www.mapquest.com and Google Earth.

The initial list of sites was screened based on the structure being representative of a subgroup of structures (e.g., docks, marinas); its potential accessibility for field work; and permission from the lessee to access the site.

## SITE RECONNAISSANCE

ENTRIX personnel conducted a rapid field reconnaissance of the initially selected sites to obtain the following information:

- Actual location of the target facility and geographic coordinates.
- The best access to the site whether over land or by water, as well as special needs for access including security provisions, facility schedules, and points of contact.
- Whether any health and safety factors would limit field crew activities on the site.
- The configuration of the site (e.g., piling materials and layout, ramp design, associated buildings, floating dock and secondary pier arrangement).
- Optimum locations for environmental sampling within the facility.
- General shoreline and seabed characteristics (to ensure that the appropriate equipment would be selected).
- The nature of adjacent properties.

Results of the reconnaissance would help to determine which sites were the most practical to assess and would also supply the best information for the pilot study.

A single day was allotted for visiting all the sites, with actual locations documented using a global positioning system (GPS) receiver and digital color photos. Snorkeling or other in- or underwater examinations was not planned or conducted during the reconnaissance. The information acquired was used to finalize the selection of parameters and variables to be measured, as well as the final assessment data form and dictionary.

## DATA RECORDS

Draft data forms for use during the reconnaissance and pilot site assessment were designed by ENTRIX and Washington DNR personnel, and included the various parameters and variables listed below.

### General Information

- Calendar date
- Water surface conditions
- Weather conditions: cloud cover (type, percent), precipitation, approximate wind speed and direction
- Time of day
- Field crew members
- Location (street address, geographic coordinates)

### Structural Characteristics

- Activity (type, frequency)
- Construction material
- Ancillary structures (walkways, skirting)
- Existing conservation measures
- Length, width, height
- Orientation (north-south, east-west)
- Pilings or other support (spacing, type)

### Physical Environmental Characteristics

- Shoreline shading (vegetation, hill slope, buildings)
- Substrate composition (if visible)
- Tidal elevation (marine/estuarine)
- Shoreline condition (armored or other)
- Wave/stream energy
- Adjacent land use

### Light

Light measurements were planned for each site, with exact location to be determined during the pilot field study. The initial procedure for measuring light levels was as follows:

- Off the south or west side of the structure - ambient lighting conditions, in water measures, just above the substrate.
- Under the structure on the north or east side - ambient lighting conditions, in water measures, just above the substrate.

Vertical measurements for both irradiance (PAR) and illumination (lux) were to be taken at 2 meter intervals until readings for measurements reached zero.

The instrument used for measuring light intensity was the radiometer available for rent from Pooled Equipment at the University of Washington (206-543-5186). This instrument was a LI-COR Quantum Radiometer/Photometer model LI-185 and measured Quantum (10LUX), Watts per square meter, and microeinsteins per square meter per second. This meter was available for rent for $15 per day.

### Water Quality

Measurements of the water quality parameters were initially planned for both sides of the structure at the water surface and near (< 1 meter) the bottom. Results of the reconnaissance and further onsite discussion modified these plans, as described in the results section (B-3).

The instrument used for water quality measurements was a Horiba U-10 Multiparameter probe, model number DIE000, with a 10-meter cable rented from Global Water Instrumentation, Inc. (916-638-3429, internet site www.globalw.com). The instrument directly measured temperature in degrees Centigrade, pH (unitless), conductivity in micro/milli-Siemens per centimeter, turbidity in NTUs, dissolved oxygen in milligrams per liter, and salinity in parts per hundred (percent or o/o). This meter was available for rent at $200 per week plus shipping and refundable deposit. Charecteristics sampled included:

- Temperature
- pH (freshwater)
- Salinity (estuarine/marine)
- Turbidity
- Salinity (marine, estuarine)
- Conductivity (freshwater)
- Clarity (Secchi disc)
- Water depth

**Biological Environmental Characteristics**

Biological environmental characteristics were assessed via snorkel survey, as follows:

- Fish and invertebrate species composition (if possible) and abundance (direct counts or by defined category)
- Salmonid location in relation to the structure (e.g., under, within 10 m, farther than 10 m of the structure)
- Approximate location in water column
- Fish and mobile invertebrate behavior (e.g., feeding, active swimming, predator avoidance, shadow avoidance)
- Approximate fish length (2.5-cm categories)
- Presence/absence and relative abundance of submerged aquatic vegetation (SAV)
- Associated finfish and invertebrate species

# B-3 Results

## B-3.1 Personnel

Site reconnaissance and assessment personnel included the following:

### ENTRIX

- Michael Kyte, Senior Marine Biologist (reconnaissance and assessment).
- Stephanie Miller, Staff Biologist (reconnaissance and assessment).
- Martha Jordan, Assistant Vessel Operator and Wildlife Biologist (assessment only).

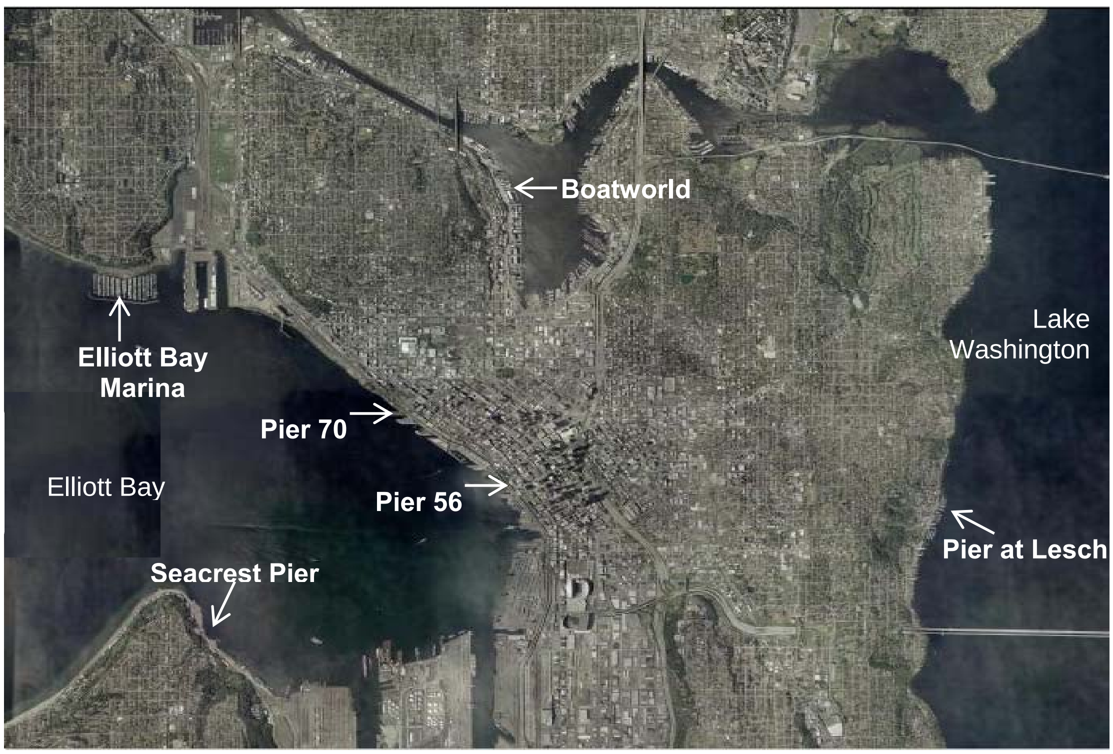
### Washington DNR, Aquatic Lands HCP (assessment only)

- Carol Cloen, Lead Scientist.
- Larry Dominguez, Scientist.
- Linda Wagoner, Planner.

## B-3.2 Reconnaissance

ENTRIX personnel conducted a rapid reconnaissance 24 January 2007 of the seven sites listed below. For each site, the general ecosystem (estuarine or lacustrine), the geographic location[4] (latitude, longitude, township, range, and section), and whether or not it was accepted or rejected for further assessment with the reasons for this decision are provided. Map locations are shown in Figure B-1. Aerial photos of each site are available at www.mapquest.com by using the street address or name (e.g., Pier 70) of the site.

**Figure B-1. Map of reconnaissance sites.**




4 Latitude and longitude are in degrees, minutes, and decimal seconds, and the datum is WGS 84.

## ELLIOTT BAY MARINA (FIGURE B-2)

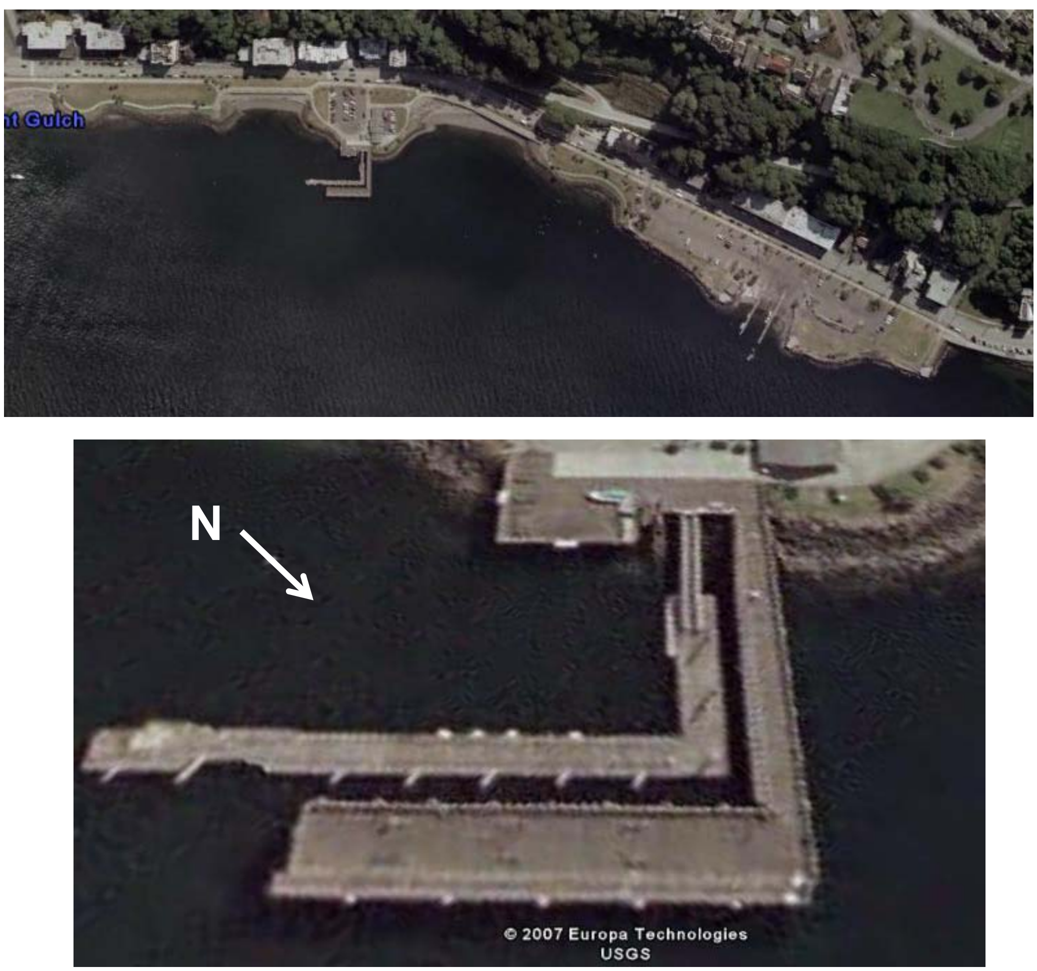
- Estuarine, Elliot Bay.
- N47 37 53.5 W122 23 13.1; T25N,R3E,sec26.
- Street address: 2601 West Marina Place, Seattle.
- Site selected for the following reasons:
    - Conservation measures in place (see B-3.3).
    - Reasonable opportunities for conservation measures available.
    - Access to the shoreline and critical structures relatively easy and direct.
    - Shaded areas clearly defined.
    - Representative of complex marinas.
    - Access to affected areas safe and practical.

**Figure B-2. Aerial view of Elliott Bay Marina and surrounding area.**


## SEA CREST PIER – ALKI FISH AND CRAB (FIGURE B-3)

- Estuarine, Elliot Bay.
- N47 35 22.3 W122 22 46.6; T24N,R4E,sec3.
- Street address: 1660 Harbor Ave SW, Seattle.
- Site selected for the following reasons:
    - Reasonable opportunities for conservation measures available (see B-3.3).
    - Access to the shoreline and critical structures relatively easy and direct.
    - Shaded areas clearly defined.
    - Representative of small to medium piers used for light commercial and recreational purposes.
    - Access to affected areas safe and practical.

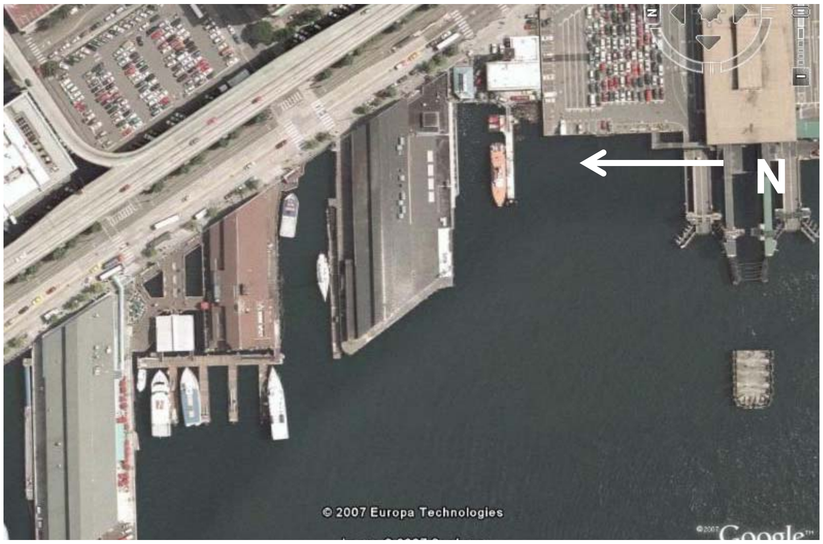
**Figure B-3. Aerial view of Seacrest Pier and surrounding area.**

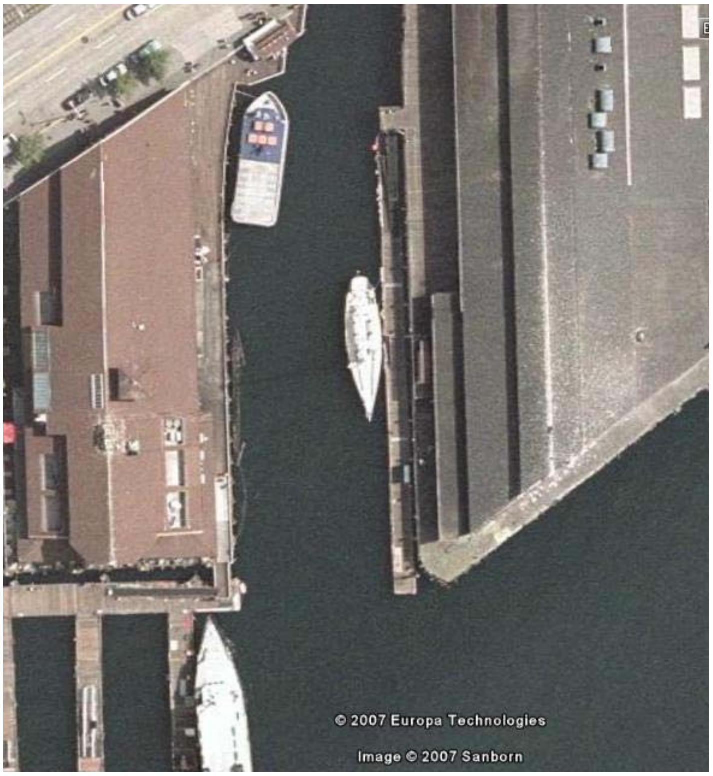


## CITY OF SEATTLE PIER 55-56 (FIGURE B-4)

- Estuarine, Elliot Bay.
- N47 36 19.0 W122 20 31.0; T24N,R4E,sec6.
- Street address: Spring Street and Alaskan Way.
- Site rejected for the following reasons:
    - No reasonable opportunities for conservation measures available.
    - Pier too large and complex.
    - Shoreline inaccessible and substantially modified.
    - No access ramps for grating.
    - Heavy commercial use.
    - Surrounded by similar commercial piers.
    - Access to the shoreline and critical structures not relatively easy and direct.
    - High commercial activity level with security considerations.
    - Access to affected areas not safe and practical.
    - Structure too large and complex to clearly define effects.
    - Adjacent land use is similar and would mask effects of target structure.

**Figure B-4. Aerial view of Pier 55-56.**



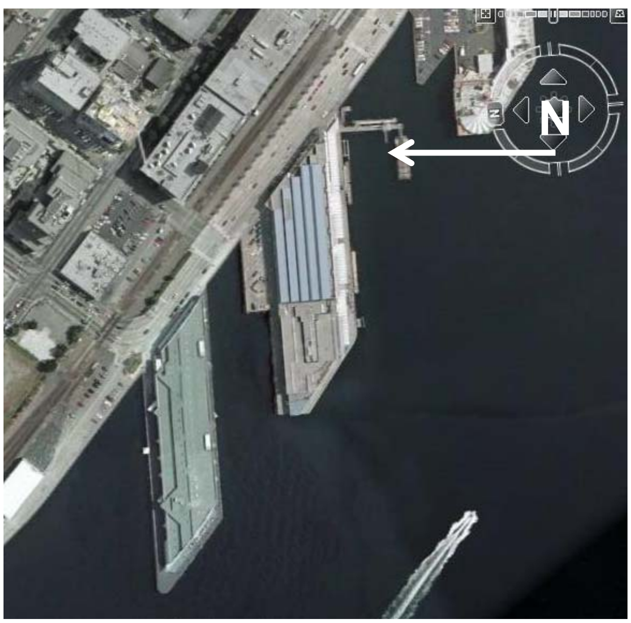




## TRIDENT PIER 70 (FIGURE B-5)

- Estuarine, Elliot Bay.
- N47 36 53.8 W122 21 26.3; T25N,R3E,sec36.
- Street address: 2901 Alaskan Way, Seattle.

- Site rejected for the following reasons:
  - No reasonable opportunities for conservation measures available.
  - Pier too large and complex.
  - Shoreline inaccessible and substantially modified.
  - No access ramps for grating.
  - Heavy commercial use.
  - Conservation measure of replacing creosote-treated wood piling with steel in progress.
  - Access to the shoreline and critical structures not relatively easy and direct.
  - High commercial activity level with security considerations.
  - Access to affected areas not safe and practical.
  - Structure too large and complex to clearly define effects.

**Figure B-5. Aerial view of Pier 70 and surrounding area.**




## BOAT WORLD (FIGURE B-6)

- Lacustrine, Lake Union.
- N47 38 21.1 W122 20 26.1; T25N,R4E,sec19.
- Street address: 2450 Westlake Ave. N., Seattle.
- Site selected for the following reasons:
    - Reasonable opportunities for conservation measures (see Results).
    - Access to the shoreline and critical structures relatively easy and direct.
    - Shaded areas clearly defined.
    - Representative of complex marinas in lacustrine ecosystems.
    - Access to affected areas safe and practical.
    - However, snorkel survey not practical because of water temperatures and security considerations.

**Figure B-6. Aerial view of Boat World and surrounding area.**


## LESCHI (FIGURE B-7)

- Lacustrine, Lake Washington.
- N47 36 05.6 W122 17 01.5; T24N,R4E,sec3.
- Street Address: 120 Lakeside Way, Seattle.
- Site rejected for the following reasons:
    - No reasonable opportunities for conservation measures available.
    - Facility too large and complex with numerous finger piers, floating docks, and offshore breakwater.
    - Shoreline inaccessible and substantially modified.
    - Associated shoreline buildings constructed on and over the shoreline.
    - No access ramps for grating.
    - Areas under piers walled off.
    - Heavy recreational use.
    - Access to the shoreline and critical structures not relatively easy and direct.
    - High level of recreational boat activity with likely security considerations.
    - Typical of lakeside marinas, but would be redundant because of assessment at Boat World.
    - Access to affected areas not practical.
    - Structure too large and complex to clearly define effects.
    - Snorkel survey not practical because of water temperatures, complex structure, and security considerations.

## CITY OF SEATTLE LESCHI PIER (FIGURE B-8)

- Lacustrine, Lake Washington (Figure 1 map code “LESCHI”).
- N47 36 05.6 W122 17 01.5, N47 36 05.6 W122 17 01.5
- Street Address: 100 Lakeside Way, Seattle.
- Site selected for the following reasons:
    - Reasonable opportunities for conservation measures available (see Results).

- Access to the shoreline and critical structures relatively easy and direct.
- Shaded areas clearly defined.
- Representative of small to medium piers used for light commercial and recreational purposes.
- Access to affected areas safe and practical.

**Figures B-7 & B-8. Aerial view of the area surrounding Leschi and the City's Piers**


## B-3.3 Pilot Site Assessment

ENTRIX and Washington DNR personnel conducted the pilot field site assessment at four sites 30 and 31 January 2007. During the site assessments, quantitative information was collected where possible on field data sheets on the various parameters and variables listed in Tables 3-5 and 3-6. These data are presented below in the form of bulleted lists by site, with comments on existing and potential conservation measures. Information on location presented previously is not repeated in this section. In addition, information on leases of aquatic land including owner and contact information is not included, because it is available in the Washington DNR NaturE database.

# B-4 Discussion - problems and solutions

Unlike traditional discussion sections, this section does not interpret the collected data. Rather, it focuses on the factors that influenced the data collection and observations; problems encountered and proposed solutions to those problems. The information collected during this pilot field study and the solutions proposed can be used to in the design of a final effectiveness monitoring plan.

The data and observations recorded during the reconnaissance and site assessments can only be considered as snapshots without continuing monitoring or further study. Conditions at all the sites can and do change frequently and substantially causing measurements made at a single point in time to be less important and the meaning of the information unclear unless compared with additional data. However, the information collected in the pilot field study can be used for two purposes: first, as a baseline against which further investigation can be compared; second, these results serve as a demonstration of the magnitude of the various parameters and variables of interest, and can be used to design future studies and/or monitoring.

Several factors, including a number of problems, were encountered, some of which caused the collected data to be questionable. These are discussed in the following separate sections.

## B-4.1 Data Use and Applicability

### PROBLEM

Water quality and light data collected in this pilot study are useful for comparison between sites and within ecosystems for the pilot field assessment. However, because of several factors, listed below, these data should not be used as a baseline for future monitoring.

- The rented radiometer could not be calibrated against standard light sources.
- The previous use and any problems with the radiometer was unknown.
- Different people with varying degrees of training and experience will be conducting future monitoring.

- Sites and facilities will differ.
- Onsite environmental conditions will differ (e.g., time of day, weather, tide level, water quality)
- Goals and objectives of the monitoring will differ from those of the pilot study.

### SOLUTION

Any long-term monitoring program should have an established design with clear goals and objectives, dedicated, calibrated, and maintained instruments, and personnel experienced and trained with the program methods and procedures. This instrument could be maintained and periodically calibrated to ensure reliable and defensible data.

## B-4.2 Vehicular Traffic

### PROBLEM

Pacific Northwest urban traffic is infamous for its volume and congestion, as shown by frequent numerous stories in the news media and the experience of the site assessment team. A substantial delay of over one and one half hours was caused on the first day of the site assessment by a number of accidents and other factors causing the normally slow traffic on Interstate 5 to be even slower to the point of standing still.

### SOLUTION

Whenever possible, field teams should attempt to avoid peak rush hours. In addition, survey personnel should avail themselves of the various traffic reporting services on commercial broadcast radio, television, and the internet. This information, combined with communication and flexibility in route and time, can be used to sometimes avoid severe delays.

## B-4.3 Weather

### PROBLEM

Weather can cause simple delays in the form of traffic congestion in response to rain, fog, or snow, or it can create hazardous situations. In addition, wind and other factors can develop relatively quickly and catch an unaware crew unprepared resulting in a hazardous situation. The pilot field study was fortunate in that the survey personnel enjoyed calm, clear, and mild weather. Snow, rain, wind, fog, or strong winds were all strong potential problems at this time of year.

In addition, weather can strongly influence the quality and quantity of collected data and biological observations. Strong winds resulting in choppy water conditions can and did cause in-water light measurements to vary substantially. Fog, low overcasts, and precipitation can also influence not only light and water quality measurements but also the behavior of fish and mobile invertebrates.

### SOLUTION

A number of weather forecast services are available including commercial broadcasts, and the National Weather Services internet sites and VHF marine radio broadcasts. It is imperative that survey personnel monitor weather conditions not only in the target area but also between their point of origin and the survey area. Flexibility in schedules and the order in which sites are visited can alleviate weather-induced delays. In addition, it is important that survey personnel be familiar with potential weather conditions in the survey area, especially if small boats are used. In any case, careful attention should be paid to weather conditions, and they should be assiduously recorded on the data forms.

## B-4.4 Vessel or Vehicle Breakdown

### PROBLEM

Reconnaissance personnel experienced a mechanical failure of the outboard engine on the skiff that they initially used. This failure was quickly and safely addressed by using a commercial vessel assist or towing service. The problem demonstrated the potential of equipment mechanical breakdowns to interfere with survey or monitoring activities and to potentially create hazardous conditions.

### SOLUTION

Because most of the monitoring activities are likely to occur in urban environments, survey personnel can easily subscribe to and use commercial vehicle (e.g., AAA) and vessel (e.g., US Boat Vessel Assist) towing services. Personnel should also be familiar with other emergency services and their limitations including 911 and the Coast Guard.

## B-4.5 Timing of Sampling

### PROBLEM

A number of problems occurred resulting from the timing of the pilot study:

- High tides prevented observations of low intertidal and upper subtidal zone conditions.
- The winter season prevented potential observation of outmigrating salmonids, recreationally and commercially important finfish and invertebrates, and submerged aquatic vegetation.
- The winter season caused low air and water temperatures that interfered with snorkeling activities and could have caused a hazardous situation through hypothermia.
- The time of day strongly influenced light intensity measurements and assessments of the shadowing effects of structures (e.g., a low afternoon sun angle prevents light from penetrating grated ramps).

### SOLUTION

Many of these problems caused by timing, daily, seasonal, tidal, can be avoided by scheduling the site assessment or monitoring in the appropriate period. In particular, light measurements should be made a standard time, probably when the sun is within an acceptable range of degrees above the horizon.

## B-4.6 Obtaining and recording data and observations

### PROBLEM

The reconnaissance and site assessment personnel encountered a number of problems associated with data acquisition and recording:

- Lack of current and reliable information on location and configuration of target facilities.
- Confusing messages and directions from members of the survey party.
- Lack of adequate preparation in the form of clear plans or guidelines for collecting data at each site.
- Inadequate design of data forms.
- Lack of a prior clear stated purpose of the site assessment at each site.

Most of these problems arose because the pilot field study was a demonstration and an exploration or test of approaches and methods. These problems would likely disappear with better planning of a monitoring or assessment program. However, some factors, unless recognized and addressed, can cause data collection and subsequent interpretation to include inaccuracies and inadequacies. For instance, because of the lack of a checklist, the dimensions of some structures were not obtained, water depths were not measured at appropriate locations, some light measurements were not recorded, and recorded data were difficult to transpose to electronic records.

### SOLUTION

Because of current information technology and the experience gained from the pilot assessments, a number of solutions can be implemented:

- Obtain accurate facility locations (e.g., street addresses and/or geographic coordinates).
- Create drawings of target structures or facilities from available aerial photos (e.g., www.mapquest.com, Google Maps).
- Indicate on the drawings where observations will be made and what data will be collected.
- Create and follow a checklist for obtaining data.

- Create data forms that match the data collection strategy. It is highly likely that the data collection forms will have to be customized to accommodate features unique to each site. An alternate tactic would be to use electronic means (e.g., ruggedized portable computer) for data collection with onsite print out and data backup for verification and protection.
- Assign clear and specific roles and duties for data collection to field team members.

# Appendix C – Conservation Measures

Table C-1 contains the list of conservation measures evaluated in the course of this project. It also identifies which of these were classified as "implementation" and which were identified as "effectiveness" measures. Although the process for distinguishing between implementation and effectiveness measures is somewhat subjective, the following criteria were used:

- Is the currency of the monitoring programmatic or ecological?
- Is the wording of the conservation measure sufficiently specific as to be testable?

**Table C-1. Proposed conservation measures and monitoring category**

| | Measure | Implementation | Effectiveness |
|---|---|---|---|
| Aquaculture | Restrict noise and light to harvesting activities, normal operational practices and/or maintenance of safety. | X | |
| | Make every reasonable effort to minimize noise and lights during nighttime operations. | X | |
| | Use durable, long life materials for site maintenance and construction (e.g., wrapped Styrofoam). | | X |
| | Minimize wheeled vehicles from driving on/in intertidal areas (e.g., eelgrass beds, salt marsh). | X | |
| | Prevent release of contaminants from equipment into the environment. | X | |
| | Prevent the use or discharge of toxic chemicals to control the fouling of net. | X | |
| | Prevent discharge of sanitary waste. | X | |
| | Prevent pressure washing or cleaning of machinery in intertidal habitats. | X | |
| | Minimize the risk of spills from vessels and equipment through appropriate design, employing appropriate containment devices (such as drip pans), and ensuring prompt cleanup of all spills and leaks. | X | |
| | Store all chemicals, fuels and lubricants off site. | X | |
| | Recover and dispose all debris and garbage at an appropriate upland facility. | X | |
| | Develop and follow a best management plan (BMP) for sewage and liquid waste that addresses: toilet facilities; handling and discharge of graywater; Transportation and disposal of sewage and liquid waste. | X | |

| | Measure | Implementation | Effectiveness |
|---|---|---|---|
| | Develop and maintain a spill response kit with appropriate equipment, information for notification of authorities and a training plan for employees. Amend the plan whenever operational practices are altered. | X | |
| | Follow practices that minimize the buildup of released biofouling organisms onto benthic environments. | X | |
| | Minimize the discharge of unconsumed feed. | X | |
| | Minimize the discharge of accumulated solids and attached marine growth. | X | |
| | Minimize harvest/culture where seagrasses or kelp are present; if presence is unavoidable, map aquatic vegetation by species and area and monitor for impacts to determine if mitigation is necessary. | X | |
| | Prevent damage/destruction of Covered Species or their habitats in the harvest/culture area. | X | |
| | Prevent harvest or in-water maintenance and construction during Covered Species migration windows. | X | |
| | Develop and maintain a disease diagnosis and response plan, documenting import and transfer requirements as well as procedures for stock certification; disease containment and eradication; and control chemical use. | X | |
| | Prevent commercial harvesting in areas with densities of native hard shell clams less than $2.7/m^2$, or geoduck clam densities less than $0.2/m^2$ | X | |
| | Ensure that net pen structures have webbing of appropriate size to prevent entanglement by Covered Species and their prey. | | X |
| | Ensure that predator netting is of appropriate size to avoid entrapment and injury to Covered Species and their prey, and made of material that is tightly secured and regularly inspected. | | X |
| **Log Booming and Storage** | Site log transfer facilities to avoid bald eagle nests (or other Covered Species' nests). No project construction or operation should be closer than 330 feet to any bald eagle nest tree unless permitted by U.S. Fish and Wildlife Service. | X | |
| | Site log storage areas and transfer facilities in areas with good currents and tidal exchanges. | | X |
| | Storage of logs should not take place where they will *ground* at any time. | | X |
| | Storage and handling of logs should be restricted or eliminated from waters where state and federal water quality and sediment standards cannot be met at all times. | | X |
| | Avoid siting log storage areas and facilities in sensitive habitat and areas important for specified species (e.g., salt marshes, kelp or eelgrass beds, seaweed harvest areas or shellfish concentration areas). | X | |

| | Measure | Implementation | Effectiveness |
|---|---|---|---|
| Overwater Structures | Ammoniacal Copper Quaternary (ACQ) treated wood may not be used in marine environments. Require replacement on existing structures that are determined extremely detrimental within 10 years. | X | |
| | Assess water drainage and runoff patterns and alter them to reduce direct inputs. | | X |
| | Avoid casting artificial light into the ambient night-time aquatic environment. Orient night lighting such that illumination of the surrounding waters is avoided. | | X |
| | Avoid use of treated wood timbers or pilings to the extent practicable (including during replacement/maintenance). Use of alternative materials such as untreated wood, concrete, or steel is recommended. This incorporates C35 (metal-salt treated wood should not be used in conditions of low water hardness, low pH, where elevated background metals exist, or where metals-sensitive biota, such as shellfish, are prevalent). | | X |
| | Cover Styrofoam floatation material so Styrofoam cannot escape throughout the useable life of the float. | | X |
| | Deploy anchorage systems in a manner that prevents dragging. | | X |
| | Do not allow new, additional filling of lands. | X | |
| | Encourage only seasonal use of docks and off-season haul-outs. | X | |
| | Ensure that the length of mooring lines between the anchor and the subsurface float exceed the water depth as measured at extreme high tide plus 20%. | | X |
| | Floats shall not rest on the tidal substrate and must use stoppers or supports that keep the bottom of the floatation device at least 1 (one) foot above the level of the substrate. *Ground* | | X |
| | Include low-wake vessel technology, appropriate routes, and best management practices for wave attenuation structures as part of the design and permit process. Vessels should be operated at sufficiently low speeds to reduce wake energy, and no-wake zones should be designated near sensitive habitats. This incorporates the use of floating breakwaters, where possible and removal during periods of low dock use. | | X |
| | Incorporate best management practices to prevent or minimize contamination from ship bilge waters, antifouling paints, shipboard accidents, shipyard work, maintenance dredging and disposal, and non-point source contaminants from upland facilities related to vessel operations and navigation. | X | |

| | Measure | Implementation | Effectiveness |
|---|---|---|---|
| | Incorporate measures that increase the ambient light transmission under piers and docks during daylight hours. These measures include, but are not limited to, maximizing the height of the structure and minimizing the width of the structure to decrease shade footprint; grated decking material; using solar tubes to direct light under the structure and glass blocks to direct sunlight under the structure; illuminating the under structure area with metal halide lamps and use of reflective paint or materials (e.g., concrete or steel instead of materials such as wood that absorb light) on the underside of the dock to reflect ambient light reduce duration of light limitation. | | X |
| | Incorporate measures that increase the ambient light transmission under piers and docks. These measures include, but are not limited to, maximizing the height of the structure and minimizing the width of the structure to decrease shade footprint (replacement maintenance); grated decking material; using solar tubes to direct light under the structure and glass blocks to direct sunlight under the structure; illuminating the under structure area with metal halide lamps and use of reflective paint or materials (e.g., concrete or steel instead of materials such as wood that absorb light) on the underside of the dock to reflect ambient light. | | X |
| | Locate floats in deep water to avoid light limitation and grounding impacts to the intertidal zone, and maintain at least one foot of water between the substrate and the bottom of the float during low water | | X |
| | Maintain dredged basins with more than one water depth so that depth decreases with distance from the entrance to avoid internal deeper pockets that can act as unflushed holding basins. | | X |
| | Minimize changes to natural sediment processes and avoid effects to wave energy that determine characteristics of adjacent habitats during operation and maintenance activities. | X | |
| | No large woody debris may be removed during construction or operation. | X | |
| | Orient night lighting such that illumination of the surrounding waters is avoided. | | X |
| | Perform maintenance activities using environmental windows that protect spawning periods and periods of presence of Covered Species. | X | |
| | Place shallow draft vessels nearshore to avoid the need for dredging. | X | |
| | Prevent work over or in close proximity to submerged vegetation. | | X |
| | Remove existing skirting and do not authorize its replacement during maintenance activities. | | X |

| | Measure | Implementation | Effectiveness |
|---|---|---|---|
| | Require subsurface float to prevent the line from dragging on the bottom during low water. | | X |
| | Situate buoys so that vessels do not *ground* out at low water and require midline float systems. | | X |
| | Use environmental windows for any maintenance activities (and operations to the extent possible) that include protection for spawning periods and periods of presence of juvenile salmonids, forage fish, groundfish, and Dungeness crab. | X | |
| | Use materials such as steel, concrete, recycled plastic, anchors and elastic rods or alternative dock mooring systems when replacing structure parts during maintenance. | | X |
| | Use upland boat storage whenever possible to minimize need for overwater structures. | X | |

# Appendix D – Proposed Covered Species, Habitats, and Activities

**Table D-1. Proposed Covered Species.**

| Group | Species | Listing Status/Rank | |
|---|---|---|---|
| | | **Federal** | **State** |
| **Amphibians & Reptile** | Columbia spotted frog | Concern | Candidate |
| | Northern leopard frog | Concern | Endangered |
| | Western toad | Concern | Candidate |
| | Western pond turtle | Concern | Endangered |
| **Birds** | Bald eagle | Concern | Threatened |
| | Black tern | Concern | Monitor |
| | Brown pelican | Endangered | Endangered |
| | Common loon | None | Sensitive |
| | Harlequin duck | None | None |
| | Marbled murrelet | Threatened | Threatened |
| | Western snowy plover | Threatened | Endangered |
| **Fish** | Bull trout/Dolly Varden | Threatened | Candidate |
| | Chinook salmon | Endangered or Threatened | Candidate |
| | Chum salmon | Threatened | Candidate |
| | Coastal cutthroat | Concern | None |
| | Coho salmon | Threatened | None |
| | Pink salmon | None | None |
| | Sockeye/kokanee salmon | Endangered or Threatened | Candidate |
| | Steelhead | Threatened | Candidate |
| | Green sturgeon | Endangered (southern DPS) | Monitor |
| | White sturgeon | None | None |
| **Marine Mammal** | Southern resident killer whale | Endangered | Endangered |

**Table D-2. Covered activity groups, subgroups.**

| Activity Group | Activity Subgroup |
|---|---|
| Aquaculture | Finfish |
| | Shellfish |
| Log booming and storage | |
| Overwater structures – single element | Boat ramp, Launch, Hoist |
| | Docks and wharf |
| | Rafts and floats |
| | Floating homes |
| | Mooring buoy |
| | Nearshore building |
| Overwater structures – multiple element | Marinas |
| | Shipyards and terminal |

**Table D-3. Characteristics of ecosystems and habitats used in the Washington DNR ESA compliance process.**

| Ecosystem | Region/Class | Habitat | Characteristics |
|---|---|---|---|
| Saltwater - Offshore | | | ▪ Depth greater than 20 meters<br>▪ Benthic habitat below the photic zone<br>▪ Energy production derived from water column phytoplankton communities<br>▪ Dominated by unconsolidated sediments |
| | Coastal | | ▪ Unconsolidated habitats dominate, with consolidated habitats concentrated off the Olympic coast, west and southwest of Willapa Bay, and off Cape Flattery |
| | Inland | | ▪ Unconsolidated habitats dominate, with consolidated habitats concentrated off the San Juan Islands, the west coast of Whidbey Island and Admiralty Inlet, and the Tacoma Narrows |
| | | Consolidated | ▪ Substrate - rocks larger than cobble (265 millimeters in diameter), bedrock and consolidated clays<br>▪ Biota - high to moderate energy regimes: encrusting invertebrates and plants, urchins, rockfish, gobies, lingcod and sculpins; low energy - glass sponges, serpulid polychaetes, planktivorous invertebrates, cup coral, rockfish, longfin sculpin and gobies |
| | | Unconsolidated | ▪ Substrate - cobble, gravel, sand, mud and organic materials<br>▪ Biota<br>▪ High energy (cobble and mixed-coarse substrates) - mussels, barnacles, urchins, rock scallops, small bivalves, amphipods, and polychaetes<br>▪ Low energy (mud) - sea pens and whips, polychaetes, bivalves, amphipods, anemones, sea stars, urchins and sea cucumbers |
| | | Water Column | ▪ Greater than 10 meters above the bottom<br>▪ Biota - plankton (eggs, larvae, phytoplankton, zooplankton), fish (herring, salmonids, smelt, lamprey, spiny dogfish, cods, sandlance, rockfish), birds and marine mammals |
| | | Deep | ▪ Depth greater than 200 meters |
| Saltwater - Nearshore | | | ▪ Depth less than 20 meters<br>▪ Energy primarily derived from benthic vegetation and terrestrial sources<br>▪ Benthic habitats within the photic zone<br>▪ Vegetation has significant influence on species assemblages |

| Ecosystem | Region/Class | Habitat | Characteristics |
|---|---|---|---|
| | Coastal | | ▪ Unconsolidated habitat dominates, with consolidated substrates found in scattered along the northern coast and rocky headlands in estuaries |
| | Inland | | ▪ Unconsolidated habitat dominates, with consolidated habitat most common among the San Juan Islands, and on rocky headlands in Puget Sound |
| | | Consolidated | ▪ Intertidal and shallow subtidal areas dominated by bedrock or boulder<br>▪ Biota - Macroscopic red, green and brown algae; Kelp beds used by sea otters, and a variety of fish and invertebrate species for rearing, feeding and refuge; benthic diatoms |
| | | Unconsolidated | ▪ Eelgrass meadows (approximately +0.3 meters to –10 meters mean lower low water) used by a variety of fish and invertebrates for rearing, feeding and refuge<br>▪ Flat areas of fine to coarse unconsolidated sediments near river and stream deltas and embayments not associated with freshwater systems; drift seaweeds; infauna (worms, small crustaceans and bivalves); shorebirds; abundant juvenile and adult fish; recreationally and commercially important stocks of clams<br>▪ Subestuaries characterized by variable salinity concentrations; riparian habitat, dune habitat, tidal marshes, seaweed assemblages, eelgrass meadows, and limited rocky shore habitat.<br>▪ Riparian Zone vegetated with overhanging shrubs and trees |
| | | Water Column | ▪ Greater than 10 meters above the bottom<br>▪ Biota - |
| **Tidal Wetlands** | | | ▪ Depth - mean high water to extreme higher high water<br>▪ Periodically inundated with tidal waters<br>▪ Emergent vegetation dominated by angiosperms<br>▪ Soft sediments, with anoxic subsurface conditions<br>▪ Protected from wave energies<br>▪ Significant localized freshwater input |

| Ecosystem | Region/Class | Habitat | Characteristics |
|---|---|---|---|
| Freshwater - Riverine | | | ▪ Long linear interconnected networks, comprised of patterns and processes in that occur in longitudinal, lateral, and vertical dimensions<br>▪ Unidirectional flows terminating at the confluence with a larger stream or river, marine ecosystems or a lake<br>▪ Gradient typically decreases with longitudinal distance downstream<br>▪ Structure and variability of in channel habitat determined by topography<br>▪ Energy sources, community composition and behavioral adaptations vary with increasing distance downstream<br>▪ Includes riverine wetlands |
| | | Low-gradient valley | ▪ Slopes less than 0.1 percent with sand and gravel substrates<br>▪ Channels commonly have multiple threads<br>▪ Sediment supply generally greater than the river's transport capacity. |
| | | Riffle-pool | ▪ Alternating sequences of pools, bars, and riffles with gradients of 0.1 to 2 percent<br>▪ Sinuous with a high reach to valley length ratio<br>▪ Pools typically created by scour, with deposition occurring between pools in riffles or adjacent to pools on bars<br>▪ Particle sizes comprised of gravel and/or cobble |
| | | Plane bed | ▪ Gradients between 2 and 4 percent<br>▪ Composed of intermediate substrate sizes (gravel to cobble) |
| | | Step-pool | ▪ Gradients between 4 and 8 percent<br>▪ Alternating sequences of relatively deep stream sections with flat, nonturbulent flow and shallow, steep sections with turbulent flow<br>▪ Pools formed by large boulders that restrict the flow of water, resulting in a backwater upstream of the restriction and a substantial drop in elevation downstream of the restriction |
| | | Cascade | ▪ Gradients greater than 8 percent<br>▪ Beds comprised of large boulders with channels typically confined by valley walls<br>▪ Movement of bed material is rare due to the large size of the dominant substrate and relatively shallow water depths |

| Ecosystem | Region/Class | Habitat | Characteristics |
|---|---|---|---|
| Freshwater - Lakes | | | ▪ Standing body of water located in a topographic depression that is not directly connected to the sea<br>▪ Distinguished by relatively still waters, no ocean derived salts, and an absence of perennial emergent vegetation<br>▪ Includes lacustrine wetlands |
| | Oligotrophic | | ▪ Primary productivity rates low<br>▪ Trophic State Index less than 40 |
| | Mesotrophic | | ▪ Moderate rates of primary productivity<br>▪ Trophic State Index 40 to 50 |
| | Eutrophic | | ▪ High rate of primary production<br>▪ Trophic State Index greater than 50 |
| | | Littoral | ▪ Ordinary high water waterward to a depth of 2 meters below low water or the extent of annual emergent vegetation |
| | | Limnetic | ▪ Permanently wetted lands deeper than 2 meters, with little to no attached vegetation |
| | | Profundal | ▪ Deep water benthic habitat with no vegetation |
| Freshwater Wetlands (palustrine) | | | ▪ Hydrophytic communities; undrained hydric soils; and non-soil substrates saturated with, or covered by, water at some point in the growing season<br>▪ Located in terrestrial areas adjacent to lakes and rivers (palustrine)<br>▪ Vegetation types may be forest, scrub-shrub, and emergent<br>▪ Emergent vegetation with ocean derived salinities of less than 0.5 practical salinity units (psu)<br>▪ Lacking emergent vegetation and less than 8 hectares (20 acres), with no active wave formed or bedrock shorelines, and water depths of less than 2 meters |

# Appendix E – Field data sheets

Washington Department of
Natural Resources Aquatic Lands HCP

# Monitoring Field Data Sheets

## GENERAL INFORMATION (for all sites, all site visits)

**Date:** 01-30-07 **Time of day:** 10:35

**Field Crew:** MK, SM, MJ, LD, CC

**Agreement/Lease number:** 22002673

**Location:**

Street address: Elliott Bay Marina, Inc
2601 West Marina Place Seattle, WA

Geographic coordinates: ______

**Site manager/Contact name:** Dwight Jones

Phone number: 206-285-4817; Cell: ______ Fax: ______

Additional information (e.g., security considerations, facility schedule): Floating docks have security gates preventing walking access from shore

**Known conservation measures (from Lease/easement, Exhibit B, Permits):**

**Observed Conservation Measures** (describe):

## LEASEHOLD/SITE

**Date:** 01-30-07 **Time of day:** 1035 **Lease number:** 22002673

**Classification**

Overwater structures/Complex - Dock/wharf ☒; Boat ramp/hoist/launch ☐; Nearshore building ☐; Mooring buoy ☐; Float/raft ☐; Floating home ☐; Marina ☒; Shipyard ☐; Terminal ☐

Aquaculture – Shellfish ☐; Finfish ☐

**Material/Species:**

Overwater structures/Complex –

*Pilings:* Treated wood ☒, Number ++; Concrete ☐, Number _____; Steel ☐, Number _____; Plastic ☐, Number _____

*Decking:* Treated wood ☒; Open grate ☒, Percent _____; Glass block ☐, Percent _____; Metal ☐; and??

Aquaculture -

*Species cultured:*

Oyster ☐; Clam ☐; Geoduck ☐; Mussel ☐; Salmon ☐; Herring ☐; Other _______________

*Method of culture:* Long-line ☐; Bottom ☐; Bag ☐; Raft ☐; Netpen ☐

*Type of netting:* None ☐; Plastic ☐, Mesh size __________; and???

**Frequency of use:**

Year round ☒; Fall ☐; Winter ☐; Spring ☐; Summer ☐; Monthly ☐; Intermittent ☐

**Structure: (see sketch on reverse)**

Size (meters): Length _______________ Width _______________

Height above water _______________ Height above sediments _______________

Condition: In good repair ☒; Fair ☐; Poor ☐

Comments: _______________________________________________

**Other structures present:**

Walkways ☒; Skirting ☐; Fuel dock ☒; Outfalls ☐, Number _____;

Mooring buoys ☐, Number _____; and???

Other __________, Number _____

**Orientation**: Perpendicular to shore ☒; Parallel to shore ☐; North-south ☒; East-west ☐

## WEATHER CONDITIONS

**Date:** 01-30-07 **Time of day:** 1035 **Lease number:** 22002673

**Percent cloud cover:** 0 **Fog:** Dense ☐; Moderate ☐; Light ☐

**Precipitation:** None ☒; Steady rain ☐; Showers ☐; Snow ☐

**Wind:**

Direction: N ☐; NE ☐; E ☐; SE ☐; S ☐; SW ☐; W ☐; NW ☐

Speed (?/hour): ____________

**Surface conditions:**

Calm ☒; Swells ☐; Breaking waves ☐

Wave height (meters): __________ Wave length (meters): __________

---

## OTHER ENVIRONMENTAL INFORMATION

## IN-WATER CONDITIONS

**Depth (meters):** ____________ **(feet):** ____________

**Tidal height (meters):** ____________ **(feet):** 8.8

**Substrate composition:** Mud ☐; Sand ☐, Percent _____; Cobble ☐, Percent _____;

Boulder, Percent _____;

**Wave/Stream Energy:** High ☐; Medium ☐; Low ☐

**Adjacent land use:** Industrial ☒; Urban ☐; Residential ☐; Rural ☐

**Shoreline condition:**

Riparian vegetation[1]: Type: __________ Percent __________

Condition[2]: ____________

Comments: ____________

school of ~100 sm. herring passing while doing WQ

---

[1] Types: N=Native,O= Ornamental, T=Trees, S= Shrubs, G= Grasses

[2] Condition: S= Steep slope/bluff, G= Gradual, B= Beach, WD= Woody Debris, BH= Bulkhead

## LIGHT PENETRATION

**Date:** 01-30-07 **Time of day:** 11.10 **Lease number:** 22002673

**IN-WATER CONDITIONS (offshore end of structure)**

shaded by boat

| Parameter | Depth: W 1 meter E | | ≤ 1meter off bottom W 5 m E 5.4 m | |
|---|---|---|---|---|
| Temperature (Celsius) | 7.4 | 7.8 | W 8.6 | E 8.6 |
| Salinity % | 2.7 | 2.71 | 2.79 | 2.8 |
| pH | 7.6 | 8.27 | 8.06 | 8.28 |
| Conductivity | 43.2 | 43.3 | 44.4 | 45.0 |
| Turbidity (NTU) | 1 | 1 | 1 | 1 |
| Dissolved Oxygen | 8.56 | 8.6 | 7.88 | 8.53 |
| Clarity (secchi disk) | bottom: 5.6 m | | 4.8 | |

**LIGHT – IRRADIANCE (PAR) – SURFACE*** Atm. W 850; E 2900

shaded by boat

| Distance from or under structure | Irradiance (PAR) South or west side | Irradiance (PAR) North or East side | Illumination (ILux) South or west side | Illumination (ILux) North or East side |
|---|---|---|---|---|
| 0.5 M | 220 ~~180~~ ~~66~~ | | 66 ~~55~~ ~~120~~ | |
| 2 | | | | |
| ~~4~~ 3 | 170 | | 46.0 | |
| 6 | | | | |
| 8 | | | | |
| 10 | | | | |
| 20 | 180 | | 55 | |
| ~~30~~ 22 | 255 | ~~255~~ | | |

**LIGHT – IRRADIANCE (PAR) - ≤ 1 M FROM BOTTOM*** 10 ft / bottom

bottom 11 ft

| Distance from or under structure | Irradiance (PAR) South or west side (5) | Irradiance (PAR) North or East side | Illumination (ILux) South or west side (5) | Illumination (ILux) North or East side |
|---|---|---|---|---|
| 0.5 | 120 | | ~~45~~ 37 | |
| 2 | | | | |
| ~~4~~ 3 (10 ft) | 200\140 | | 120\37 | |
| 6 | | | | |
| 8 | | | | |
| 10 | | | | |
| 20 | 430 (110) | | 12.5 (330) | |
| ~~30~~ 22 | (10) 600 (b) 105 | | | |

- **Note whether the location of the measurement is within or outside of the shade and/or physical footprint:**
- **'U' = under, 'O' = outside, 'S' = shaded, 'E' = exposed as not within physical footprint.**

Elliot Bay Marina

Water Quality

| | West 1M | West Bottom (5M) | East 1M | East bottom (5.4m) |
|---|---|---|---|---|
| Temp | 7.4 | 8.6 | 7.8 | 8.6 |
| Salinity | 2.7 | 2.79 | 2.71 | 2.8 |
| pH | 7.6 | 8.06 | 8.27 | 8.28 |
| cond. | 43.2 | 44.3 | 43.3 | 45.0 |
| turb. | 1 | 1 | 1 | 1 |
| DO | 8.56 | 7.88 | 8.6 | 8.53 |
| secchi disk | 5.6m | | 4.8m | |

Light air: 2900 PAR / 850 LUX

| Distance (west) | surface PAR | surface LUX | 10f PAR | 10f LUX | bottom PAR | bottom LUX |
|---|---|---|---|---|---|---|
| .5 m | 220 | 66 | 120 | 37 | | |
| 3 m | 170 | 46 | 200 | 120 | 140 | 37 |
| 20 m | 180 | 55 | 43 | 12.5 | 110 | 33 |
| 22 m | 255 | | 600 | | 105 | |

Washington Department of
Natural Resources Aquatic Lands HCP

# Monitoring Field Data Sheets

## GENERAL INFORMATION (for all sites, all site visits)

**Date:** 01-30-07 **Time of day:** 1415

**Field Crew:** MK, SM, MJ, CC, LD

**Agreement/Lease number:** 22076646

**Location:**

Street address: Seacrest Boathouse and Pier
1660 Harbor Ave SW Seattle, WA

Geographic coordinates: ____________

**Site manager/Contact name:** City of Seattle

Phone number: ____________; Cell: ____________ Fax: ____________

Additional information (e.g., security considerations, facility schedule):

**Known conservation measures (from Lease/easement, Exhibit B, Permits):**

**Observed Conservation Measures** (describe):

seasonal dock only in summer

## LEASEHOLD/SITE

**Date:** 01-30-07 **Time of day:** 1415 **Lease number:** 22076646

**Classification**

Overwater structures/Complex - Dock/wharf ☒; Boat ramp/hoist/launch ☐; Nearshore building ☒; Mooring buoy ☐; Float/raft ☐; Floating home ☐; Marina ☐; Shipyard ☐; Terminal ☐

Aquaculture – Shellfish ☐; Finfish ☐

**Material/Species:**

Overwater structures/Complex –

*Pilings:* Treated wood ☒, Number ++; Concrete ☐, Number _____; Steel ☐, Number _____; Plastic ☐, Number _____

*Decking:* Treated wood ☒; Open grate ☒, Percent _____; Glass block ☐, Percent _____; Metal ☐; and??

Aquaculture -

*Species cultured:*

Oyster ☐; Clam ☐; Geoduck ☐; Mussel ☐; Salmon ☐; Herring ☐;

Other ____________________

*Method of culture:* Long-line ☐; Bottom ☐; Bag ☐; Raft ☐; Netpen ☐

*Type of netting:* None ☐; Plastic ☐, Mesh size _________; and???

**Frequency of use:**

Year round ☒; Fall ☐; Winter ☐; Spring ☐; Summer ☐; Monthly ☐; Intermittent ☐

**Structure: (see sketch on reverse)**

Size (meters): Length ____________ Width ____________

Height above water 7.5 ft. Height above sediments ____________

Condition: In good repair ☐; Fair ☑; Poor ☐

Comments: ____________________________________________

____________________________________________

____________________________________________

**Other structures present:**

Walkways ☒; Skirting ☐; Fuel dock ☐; Outfalls ☐, Number _____;

Mooring buoys ☐, Number _____; and???

Other floating dock, Number 1

**Orientation**: Perpendicular to shore ☒; Parallel to shore ☒; North-south ☐; East-west ☐

## WEATHER CONDITIONS

**Date:** 01-30-07 **Time of day:** ___________ **Lease number:** 22076646

**Percent cloud cover:** ⊘ ___________ **Fog:** Dense ☐; Moderate ☐; Light ☐

**Precipitation:** None ☒; Steady rain ☐; Showers ☐; Snow ☐

**Wind:**

Direction: N ☐; NE ☐; E ☐; SE ☐; S ☐; SW ☐; W ☐; NW ☐

Speed (?/hour): ___________

**Surface conditions:**

Calm ☒; Swells ☒; Breaking waves ☐

Wave height (meters): ___________ Wave length (meters): ___________

## OTHER ENVIRONMENTAL INFORMATION

## IN-WATER CONDITIONS

**Depth (meters):** ___________ **(feet):** ___________

**Tidal height (meters):** ___________ **(feet):** 10.2

**Substrate composition:** Mud ☐; Sand ☐, Percent _____; Cobble ☐, Percent _____;

Boulder, Percent _____;

**Wave/Stream Energy:** High ☐; Medium ☒; Low ☐

**Adjacent land use:** Industrial ☒; Urban ☐; Residential ☒; Rural ☐

**Shoreline condition:**

Riparian vegetation[1]: Type: ___________ Percent ___________

Condition[2]: ___________

Comments: ___________

[1] Types: N=Native, O= Ornamental, T=Trees, S= Shrubs, G= Grasses
[2] Condition: S= Steep slope/bluff, G= Gradual, B= Beach, WD= Woody Debris, BH= Bulkhead

cont on pg 2 attached

## LIGHT PENETRATION

**Date:** 01-30-07 **Time of day:** 1415 **Lease number:** 22076646

### IN-WATER CONDITIONS (offshore end of structure)

| Parameter | Depth 5.2 m | |
|---|---|---|
| | 1 meter | ≤ 1meter off bottom |
| Temperature (Celsius) | 8.3 | 8.4 |
| Salinity | 2.77 | 2.78 |
| pH | 8.56 | 8.79 |
| Conductivity | 44.1 | 44.3 |
| Turbidity | 0 | 0 |
| Dissolved Oxygen | 10.67 | 10.6 |
| Clarity (secchi disk) | bottom: 4.3 m | |

### LIGHT – IRRADIANCE (PAR) – SURFACE* Air 3000/750

Floating Dock

unshaded

wave action disturbing readings

| | Irradiance (PAR) | | Illumination (ILux) | |
|---|---|---|---|---|
| Distance from or under structure | South or west side | North or East side | South or west side | North or East side |
| 0.5 | 900 | | 250 | |
| 2 | | | | |
| 4 | | | | |
| 6 | | | | |
| 8 | | | | |
| 10 | | | | |
| 20 | | | | |
| 30 | | | | |

### LIGHT – IRRADIANCE (PAR) - ≤ 1 M FROM BOTTOM* (4.5 m)

| | Irradiance (PAR) | | Illumination (ILux) | |
|---|---|---|---|---|
| Distance from or under structure | South or west side | North or East side | South or west side | North or East side |
| 0.5 | 45 | | 500 | |
| 2 | | | | |
| 4 | | | | |
| 6 | | | | |
| 8 | | | | |
| 10 | | | | |
| 20 | | | | |
| 30 | | | | |

- **Note whether the location of the measurement is within or outside of the shade and/or physical footprint:**
- **'U' = under, 'O' = outside, 'S' = shaded, 'E' = exposed as not within physical footprint.**

Seacrest

Light Readings air: 3000 PAR
750 lux

From floating dock:

| Distance from | surface PAR | surface LUX | @ depth (4.5m) PAR | @ depth (4.5m) LUX |
|---|---|---|---|---|
| .50 m | 900 | 250 | 45 | 500 |
| Under Picnic Pier | 100 | 30 | 50 | 20 |
| Under walking ramp | 90 | 25 | 75 | 25 |

ENTRIX, Inc.

**FIELD SURVEY DAILY LOG**

**Page no.**

**Date** **Job. Name/No.**

| | Time | Event/Comments |
|---|---|---|
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |
| 6 | | |
| 7 | | |
| 8 | | |
| 9 | | |
| 10 | | |
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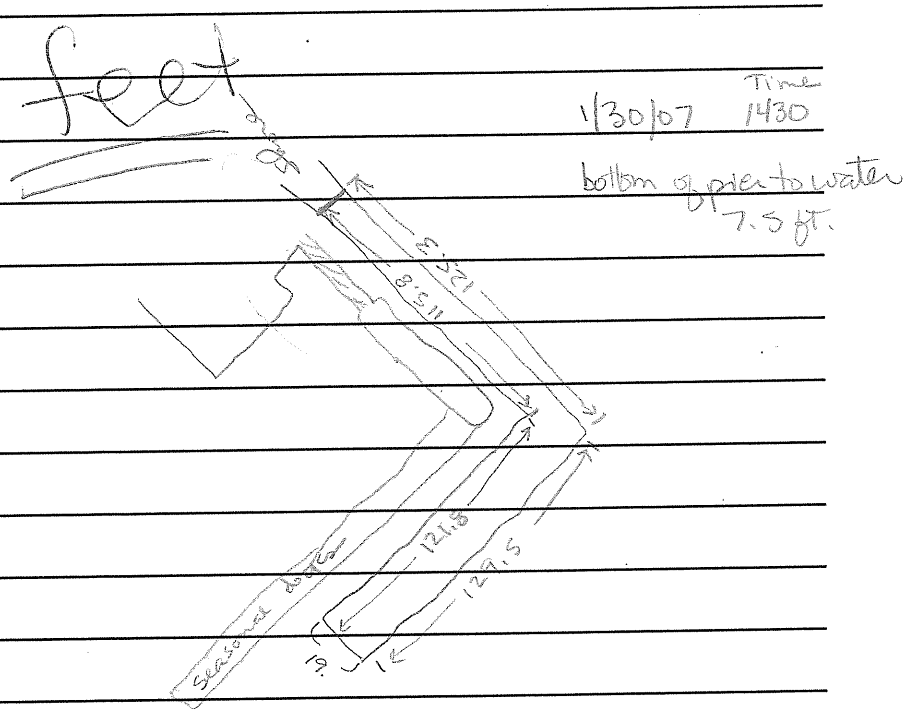
| 24 | | |
| 25 | | |



Washington Department of
Natural Resources Aquatic Lands HCP

# Monitoring Field Data Sheets

## GENERAL INFORMATION (for all sites, all site visits)

**Date:** 01-31-07 **Time of day:** 1300

**Field Crew:** ____________________

**Agreement/Lease number:** __________

**Location:**

Street address: ____________________

100 Lakeside Way Seattle, WA

Geographic coordinates: ____________________

**Site manager/Contact name:** City of Seattle

Phone number: __________; Cell: ______________ Fax: ______________

Additional information (e.g., security considerations, facility schedule):

**Known conservation measures (from Lease/easement, Exhibit B, Permits):**

**Observed Conservation Measures** (describe):

## LEASEHOLD/SITE

**Date:** 01-31-07 **Time of day:** 1300 **Lease number:** ____

**Classification**

Overwater structures/Complex - Dock/wharf ☒; Boat ramp/hoist/launch ☐; Nearshore building ☐; Mooring buoy ☐; Float/raft ☒; Floating home ☐; Marina ☐; Shipyard ☐; Terminal ☐

Aquaculture – Shellfish ☐; Finfish ☐

**Material/Species:**

Overwater structures/Complex –

*Pilings:* Treated wood ☒, Number ____; Concrete ☐, Number ____; Steel ☐, Number ____; Plastic ☐, Number ____

*Decking:* Treated wood ☒; Open grate ☐, Percent ____; Glass block ☐, Percent ____; Metal ☐; and??

Aquaculture -

*Species cultured:*

Oyster ☐; Clam ☐; Geoduck ☐; Mussel ☐; Salmon ☐; Herring ☐; Other ____

*Method of culture:* Long-line ☐; Bottom ☐; Bag ☐; Raft ☐; Netpen ☐

*Type of netting:* None ☐; Plastic ☐, Mesh size ____; and???

**Frequency of use:**

Year round ☒; Fall ☐; Winter ☐; Spring ☐; Summer ☐; Monthly☐; Intermittent☐

**Structure: (see sketch on reverse)** not incl. ramp to shore

length: ramp: 60 ft 12.1 ft wide

Size (meters): Length 142.7 ft Width 47.1 ft

top of ramp: 9.5 ft

Height above water 3 ft Height above sediments ____

Condition: In good repair ☐; Fair ☒; Poor☐

Comments: ____

**Other structures present:**

Walkways ☒; Skirting ☐; Fuel dock ☐; Outfalls ☐, Number ____;

Mooring buoys ☐, Number ____; and???

Other float dock; Number ____

**Orientation**: Perpendicular to shore ☒; Parallel to shore ☐; North-south ☐; East-west ☐

## WEATHER CONDITIONS

**Date:** 01-31-07 **Time of day:** ___________ **Lease number:** __________

**Percent cloud cover:** Ø_______________ **Fog:** Dense ☐; Moderate ☐; Light ☐

**Precipitation:** None ☒; Steady rain ☐; Showers ☐; Snow ☐

**Wind:**

Direction: N ☐; NE ☐; E ☐; SE ☐; S ☐; SW ☐; W ☐; NW ☐

Speed (?/hour): ________________

**Surface conditions:**

Calm ☒; Swells ☐; Breaking waves ☐

Wave height (meters): __________ Wave length (meters): __________

---

## OTHER ENVIRONMENTAL INFORMATION

## IN-WATER CONDITIONS

**Depth (meters):** 4.5 **(feet):** ____________________

**Tidal height (meters):** ____________________ **(feet):** ______________

**Substrate composition:** Mud ☐; Sand ☐, Percent _____; Cobble ☐, Percent _____;

Boulder, Percent _____;

**Wave/Stream Energy:** High ☐; Medium ☐; Low ☒

**Adjacent land use:** Industrial ☐; Urban ☒; Residential ☐; Rural ☐

**Shoreline condition:**

Riparian vegetation[1]: Type: ___________ Percent ___________

Condition[2]: ______________

Comments: ________________________________________________

---

[1] Types: N=Native, O= Ornamental, T=Trees, S= Shrubs, G= Grasses

[2] Condition: S= Steep slope/bluff, G= Gradual, B= Beach, WD= Woody Debris, BH= Bulkhead

## LIGHT PENETRATION

**Date:** 01-31-07 **Time of day:** 1300 **Lease number:** ___________

**IN-WATER CONDITIONS (offshore end of structure)**

| N side - unshaded<br>Parameter | Depth 4 m<br>1 meter | ≤ 1meter off bottom |
|---|---|---|
| Temperature (Celsius) | 7.2 | 6.9 |
| Salinity | 0 | 8.0 |
| pH | 8.45 | 8.64 |
| Conductivity | .096 | .096 |
| Turbidity | 0 | 0 |
| Dissolved Oxygen | 11.25 | 11.3 |
| Clarity (secchi disk) | 4.2 m - S.0. beyond bottom (bottom - N side; E side - 5.2 m) | |

**LIGHT – IRRADIANCE (PAR) – SURFACE***

direct sun on S. side

air: 1000 lux, 3500 PAR

| Distance from or under structure | Irradiance (PAR) South or west side | Irradiance (PAR) North or East side | Illumination (ILux) South or west side | Illumination (ILux) North or East side |
|---|---|---|---|---|
| ~~0.5~~ $ | 1200 | | 250 | |
| 2 | | | | |
| 4 4.5 | 150 | | 41 | |
| 6 | | | | |
| 8 | | | | |
| 10 | | | | |
| 20 | | | | |
| 30 | | | | |

**LIGHT – IRRADIANCE (PAR) - ≤ 1 M FROM BOTTOM***

shaded N side

air: 900 lux, 270 PAR

| Distance from or under structure | Irradiance (PAR) South or west side | Irradiance (PAR) North or East side | Illumination (ILux) South or west side | Illumination (ILux) North or East side |
|---|---|---|---|---|
| 0.5 | | 53 | | 170 |
| 2 | | | | |
| 4 | | 9.6 | | 2 |
| 6 | | | | |
| 8 | | | | |
| 10 | | | | |
| 20 | | | | |
| 30 | | | | |

- **Note whether the location of the measurement is within or outside of the shade and/or physical footprint:**
- **'U' = under, 'O' = outside, 'S' = shaded, 'E' = exposed as not within physical footprint.**

Washington Department of
Natural Resources Aquatic Lands HCP

# Monitoring Field Data Sheets

## GENERAL INFORMATION (for all sites, all site visits)

**Date:** 01-31-07 **Time of day:** 1010

**Field Crew:** ____________________

**Agreement/Lease number:** 20071025

**Location:**

Street address: Boatworld Marina
2146 Westlake Ave N Seattle, WA

Geographic coordinates: ____________________

**Site manager/Contact name:** Steve Burke

Phone number: 206-436-7300; Cell: ____________ Fax: ____________

Additional information (e.g., security considerations, facility schedule): Covered moorage has a security gate to prevent walking access from shore

**Known conservation measures (from Lease/easement, Exhibit B, Permits):**

**Observed Conservation Measures** (describe):

## LEASEHOLD/SITE

**Date:** 01-31-07 **Time of day:** 1010 **Lease number:** 20071025

**Classification**

Overwater structures/Complex - Dock/wharf ☒; Boat ramp/hoist/launch ☐; Nearshore building ☐; Mooring buoy ☐; Float/raft ☐; Floating home ☐; Marina ☒; Shipyard ☐; Terminal ☐

Aquaculture – Shellfish ☐; Finfish ☐

**Material/Species:**

Overwater structures/Complex –

*Pilings:* Treated wood ☒, Number ++; Concrete ☐, Number _____; Steel ☐, Number _____; Plastic ☐, Number _____

*Decking:* Treated wood ☒; Open grate ☐, Percent _____; Glass block ☐, Percent _____; Metal ☐; and??

Aquaculture -

*Species cultured:*

Oyster ☐; Clam ☐; Geoduck ☐; Mussel ☐; Salmon ☐; Herring ☐; Other ____________________

*Method of culture:* Long-line ☐; Bottom ☐; Bag ☐; Raft ☐; Netpen ☐

*Type of netting:* None ☐; Plastic ☐, Mesh size __________; and???

**Frequency of use:**

Year round ☒; Fall ☐; Winter ☐; Spring ☐; Summer ☐; Monthly ☐; Intermittent ☐

**Structure: (see sketch on reverse)**

Size (meters): Length ____________ Width ____________

Height above water ____________ Height above sediments ____________

Condition: In good repair ☒; Fair ☐; Poor ☐

Comments: ______________________________________________

______________________________________________

______________________________________________

**Other structures present:**

Walkways ☒; Skirting ☐; Fuel dock ☐; Outfalls ☐, Number _____;

Mooring buoys ☐, Number _____; and???

Other __________, Number _____

**Orientation**: Perpendicular to shore ☒; Parallel to shore ☒; North-south ☐; East-west ☐

## WEATHER CONDITIONS

**Date:** 01-31-07 **Time of day:** 1010 **Lease number:** 20071025

**Percent cloud cover:** 0 **Fog:** Dense ☐; Moderate ☐; Light ☐

**Precipitation:** None ☒; Steady rain ☐; Showers ☐; Snow ☐

**Wind:**

Direction: N ☐; NE ☐; E ☐; SE ☐; S ☐; SW ☐; W ☐; NW ☐

Speed (?/hour): ______________

**Surface conditions:**

Calm ☒; Swells ☐; Breaking waves ☐

Wave height (meters): __________ Wave length (meters): __________

## OTHER ENVIRONMENTAL INFORMATION

## IN-WATER CONDITIONS

**Depth (meters):** 4.6 **(feet):** ______________

**Tidal height (meters):** ______________ **(feet):** ______________

**Substrate composition:** Mud ☐; Sand ☐, Percent _____; Cobble ☒, Percent _____; Boulder, Percent _____;

**Wave/Stream Energy:** High ☐; Medium ☐; Low ☒

**Adjacent land use:** Industrial ☒; Urban ☒; Residential ☐; Rural ☐

**Shoreline condition:**

Riparian vegetation[1]: Type: __________ Percent __________

Condition[2]: ______________

Comments: ______________

[1] Types: N=Native, O= Ornamental, T=Trees, S= Shrubs, G= Grasses
[2] Condition: S= Steep slope/bluff, G= Gradual, B= Beach, WD= Woody Debris, BH= Bulkhead

## LIGHT PENETRATION

**Date:** 01-31-07 **Time of day:** 1010 **Lease number:** 20071025

**IN-WATER CONDITIONS (offshore end of structure)**

| Parameter | Depth 4 m — 1 meter | ≤ 1meter off bottom |
|---|---|---|
| Temperature (Celsius) | 6.4 | 6.5 |
| Salinity | 0 | 0 |
| pH | 9.0 | 8.57 |
| Conductivity | .103 | .101 |
| Turbidity | 1 | 0 |
| Dissolved Oxygen | 11.00 | 11.63 |
| Clarity (secchi disk) | D: 4.6 m SC = | 3.6 m |

- oil sheen
- direct sun

brown-gr water color

**LIGHT – IRRADIANCE (PAR) – SURFACE***

Sun

Air: 900 LUX

| Distance from or under structure | Irradiance (PAR) South or west side | Irradiance (PAR) North or East side | Illumination (ILux) South or west side | Illumination (ILux) North or East side |
|---|---|---|---|---|
| 0.5 | | ~~800~~ | | 700 |
| ~~2~~ 1 | | 800 | | 150 |
| 4 | | 80 | | 220 |
| 6 | | | | |
| 8 | | | | |
| 10 | | | | |
| 20 | | | | |
| 30 | | | | |

~~FM~~ ~~150~~

**LIGHT – IRRADIANCE (PAR) - ≤ 1 M FROM BOTTOM***

Shade

Air
7 LUX
23 PAR

| Distance from or under structure | Irradiance (PAR) South or west side | Irradiance (PAR) North or East side | Illumination (ILux) South or west side | Illumination (ILux) North or East side |
|---|---|---|---|---|
| ~~0.5~~ 1 | | .7 | | .2 |
| 2 | | 0 | | 0 |
| 4 | | | | |
| 6 | | | | |
| 8 | | | | |
| 10 | | | | |
| 20 | | | | |
| 30 | | | | |

- **Note whether the location of the measurement is within or outside of the shade and/or physical footprint:**
- **'U' = under, 'O' = outside, 'S' = shaded, 'E' = exposed as not within physical footprint.**



see back →

Light

scale: 5,000-50,000

Air: 398 lux (sun) @ end of slip

① 558 lux (shade) inside shore slips

200-2,000 scale

• near a skylight

② not under skylight

450 lux

2,000 scale

Borrowed light meter, [illegible] 2/20/07.

---

Outside Marina (direct sun)

Air: 375 (50,000 scale) lux

6000 lux / 3000 PAR

| (m) | PAR | Lux | ~~Shade~~ |
|---|---|---|---|
| .5 | 1200 | 320 | |
| 10.5 | first light | | |
| 13.5 | ∅ | ∅ | |

| | 1M | 4m | 9m |
|---|---|---|---|
| temp | 6.6 | 6.5 | 6.5 |
| sal. | ∅ | ∅ | ∅ |
| pH. | 9.08 | 8.80 | 8.69 |
| cond. | .101 | .099 | .099 |
| turb | ∅ | ∅ | ∅ |
| DO | ~~11.80~~ 10.50 | 10.56 | 10.12 |

sec. disk 4.7 m

14.5m bottom