Quality Assurance Project Plan

Benthic surveys for identifying factors related to floating kelp loss and resilience

April 2024

Habitat Strategic Initiative Lead (HSIL) grant WDFW # 23-23550 / DNR # 93-106108

Publication Information

This project has been funded wholly or in part by the United States Environmental Protection Agency (EPA) under assistance agreement PC-01J89501 to the Washington State Department of Fish and Wildlife (WDFW). The contents of this document do not necessarily reflect the views and policies of the Environmental Protection Agency or the Washington State Department of Fish and Wildlife, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

The EPA requires an approved Quality Assurance Project Plan (QAPP) for all EPA-funded projects that generate or use environmental information, including modeling efforts, before the projects begin. The plan describes the objectives of the study and the procedures to be followed to achieve those objectives. After completing the study, the author will post the final report of the study to the internet. This QAPP describes a project selected for funding through the Habitat Strategic Initiative Lead (HSIL) Request for Proposals in Fall 2022 and is described in the February 2023 Investment List for strategic investment of Puget Sound Geographic Program funds. Funds were awarded under WDFW Contract number 23-23550.

This Quality Assurance Project Plan is available at https://www.dnr.wa.gov/programs-and-services/aquatics/aquatic-science/nearshore-habitat-program.

Data for this project are available by contacting Dr. Dethier (info below). The QAPP is valid for one year from date of certification. All QAPPs for programs or projects exceeding one year in duration shall be reviewed and recertified annually.

This QAPP was approved to begin work in February 2024. It was finalized and approved in April 2024.

Contact Information:

Megan Dethier
University of Washington
Friday Harbor Laboratories (FHL)
620 University Rd, Friday Harbor WA, 98250
Phone: 206-616-0764 Email: mdethier@uw.edu

COVER PHOTO: A photo of bull kelp (*Nereocystis luetkeana*) floating at the surface taken under water. PHOTO BY KINDALL MURIE.

Quality Assurance Project Plan

Identifying factors associated with patterns in floating kelp loss and resilience through coordinated monitoring and research

by Kindall Murie, Ande Fieber, Rebecca Hansen and Megan Dethier

April 2024

Approved by:

Signature: Megan DeThier	Date: April 26, 2024
Megan Dethier, Director, University of Washington-Friday Harbor Laboratories	
Signature: Helen Berry	Date: 4/25/2024
Helen Berry, Project Manager, Department of Natural Resources	
Signature: Kindall Murie	Date: 04/26/2024
Kindall Murie, Field Manager, University of Washington	
Signature:	Date: April 26 2024
Ande Fieber, Field Manager, University of Washington	
Signature:	Date: 4/26/2024
Rebecca Hansen, Field Manager, University of Washington	
Signature: Kameron Harper	Date: 4/25/2024
Kameron Harper, Habitat Strategic Initiative Lead Subaward Manager, Washington State Department of Fish and Wildlife	
Signature:	Date:
Ken Nelson, National Estuary Program Quality Coordinator, Washington State Department of Ecology	
Signature: Ken Nelson	Date: 04/23/24

1.0 Table of Contents

List of Figures

List of Tables

2.0 Abstract

Bull kelp (*Nereocystis luetkeana*) populations appear resilient in some regions of the Salish Sea, but are declining sharply in others. To conserve this critical habitat, Washington Department of Natural Resources (DNR) seeks to better understand stressors contributing to these declines and determine appropriate management measures for specific regions.

Through coordinated monitoring, research, and synthesis of existing data by a coalition of organizations, this subaward will build on current understanding of bull kelp stressors by assessing the response of bull kelp to potential stressors across a network of sites with a wide range of environmental and ecological conditions.

While candidate stressors such as increasing temperatures, low nutrients, and grazing pressure have been identified as potential drivers of kelp loss at particular sites within the Salish Sea, stressors likely vary by location and seasonally. Increasing the spatial extent of bull kelp monitoring will help clarify sites where bull kelp condition is excellent or poor and improve our understanding of associated environmental factors.

Our project will build on existing knowledge by selecting a network of sites across a wide range of conditions and kelp response. We will develop hypotheses of key stressors through synthesis of existing datasets, with a focus on dive surveys conducted by Reef Check and water quality data; these will help focus and direct our monitoring efforts. At a network of sites, we will fill data gaps by tracking key water column parameters and floating kelp parameters related to condition. Dive surveys will build on the data synthesis to assess what is happening on the ocean floor. Findings will identify key stressors and recommend sites and parameters for a future 'monitoring backbone' that provides broad context for local studies.

3.0 Background

3.1 Introduction and problem statement

Studies have shown a distinct pattern of losses of kelp within inner basins of the Salish Sea but relative stability near the open coast; however, some notable exceptions exist and can offer important clues about kelp stressors. Information essential for habitat management and regulatory policy, and areas to target for kelp restoration or conservation efforts, will arise from comparing conditions in areas of kelp decline with those of resilient kelp beds.

Many groups are working to understand kelp ecology, restoration, and conservation, and there is an urgent need to synthesize these efforts and examine numerous potential factors of kelp declines. Because physical conditions in the Salish Sea are variable, substantial expansion is needed, particularly in benthic condition monitoring.

With only a small window of time remaining to characterize and address bull kelp stressors, the urgency of this question calls for an expansion of monitoring efforts to include an assessment of benthic conditions in both declining and resilient populations. Bull kelp abundance may be influenced during key phases of its life cycle by the benthic environment, which cannot be observed at the surface, thus driving the need for subtidal surveys of kelp habitat. This QAPP is one of three that will assess kelp conditions; other projects include the HSIL Environmental Sensor QAPP and a third project involving floating kelp surveys from the surface. Together, these efforts will provide essential, synthesized data on the causes of bull kelp decline.

3.2 Study area and surroundings

We propose intensive monitoring work at 15 sites with floating kelp (Figure 1) that capture a range of conditions throughout the Salish Sea and form a monitoring 'backbone' for comparison to other locations. Within this preliminary site list, a subset of core sites will be monitored more frequently and with additional survey parameters to capture seasonal and fine-scale changes. These core sites will be selected based on existing data synthesis and early phases of targeted benthic surveys (described in section 7). This proposed list of sites also matches with the HSIL Environmental Sensor QAPP. Below is a list of sites, collaborators and coordinates; sites with recent declines or total losses are included and noted with an asterisk (*), and coordinates are approximate:

1. Squaxin Island* (47.16767027, -122.895667). DNR long-term kelp canopy monitoring site. Co-located research with Squaxin Tribe, Puget Sound Restoration Fund (PSRF), DNR Dive Team, Reef Check.
2. Devil's Head* (47.1669336, -122.7612005). DNR long-term kelp canopy monitoring site. Co-located research with Reef Check.
3. Fox Island* (47.23295871, -122.5890455). DNR long-term kelp canopy monitoring site. Co-located research with Reef Check.
4. Salmon Beach (47.29577627, -122.5307684). DNR long-term kelp canopy monitoring site. Co-located research with DNR Dive Team, Reef Check.
5. Lincoln Park (47.53458534, -122.3979132). DNR long-term kelp canopy monitoring site. Co-located research with Reef Check.
6. Wing Point* (47.61581408, -122.4883016). DNR long-term kelp canopy monitoring site. Co-located research with PSRF.
7. Rich Passage* (47.59187299, -122.5629333). Site of documented declines (DNR).
8. Edmonds (47.82181566, -122.3765367). Co-located research with Edmonds Underwater Park, NOAA, PSRF, Northwest Straits Commission (Snohomish MRC long-term monitoring site).
9. Mukilteo * (47.84406962, -122.3458195). Co-located research with Northwest Straits Commission (Snohomish MRC long-term monitoring site).

10. North Beach (48.14509207, -122.7770934). Co-located research with Reef Check, PSRF, Northwest Straits Commission (Jefferson MRC long-term monitoring site)
11. Magnolia (47.631754, -122.399340). DNR long-term kelp canopy monitoring site. Co-located research with Reef Check, PSRF.
12. Freshwater Bay (48.143342, -123.620301). Co-located research with USGS, Sea Grant, Lower Elwha Klallam Tribe, Reef Check, Northwest Straits Commission (Clallam County MRC long-term monitoring site).
13. Cherry Point (48.85085205, -122.723114). Co-located research with Northwest Straits Commission (Whatcom MRC long-term monitoring site), DNR Cherry Point Aquatic Reserves.
14. Point Caution* (48.552264, -123.005296). Planned co-located research with University of Washington- FHL, PSRF.
15. Burrows Lighthouse (48.477656, -122.714284). Planned co-located research with Samish Indian Nation and PSRF.

Figure 1. Proposed bull kelp monitoring sites around the Salish Sea (Washington, USA) that will be surveyed to assess benthic conditions.

3.2.1 History of study area

Over the past 100 years, human population growth has led to increasing urbanization to the point where the Seattle-Tacoma area is one of the largest metropolitan areas in the US. Early in the 20th century, there was substantial unregulated logging with extensive impacts to terrestrial systems and to aquatic systems through alternation of surface hydrology and sediment loading to freshwater and marine systems. More recently, regulations have been put

in place to protect aquatic ecosystems including the marine nearshore. Nevertheless, it is anticipated that increasing effects from continued urbanization and climate change will place additional stress on the marine nearshore ecosystems, including floating kelp within these systems.

3.2.2 Summary of previous studies and existing data

In 2022-2023, an indicator development project culminated in the May 2023 release of the Washington State Floating Kelp Indicator, which encompasses the study area of this project and additional areas on the outer coast. This release presented the design and structure of the indicator as well as the first set of indicator results based on existing data. The results identified areas of floating kelp loss and areas of stability as well as areas with inadequate monitoring data to assess floating kelp condition.

The indicator results relied on several data sources. The longest monitoring record is the DNR aerial imaging surveys that started in 1989 along the Strait of Juan de Fuca as well as the outer coast. An analysis of this monitoring data published in 2018 found a broad pattern of floating kelp stability that has held in more recent years.

In contrast, a 2021 study focused on southern Puget Sound based on historical maps and contemporary monitoring data found strong loss of floating kelp. This study has played a key role in raising awareness of vulnerability in the floating kelp population and raising interest in monitoring the population and assessing causal factors, such as in the work that is the subject of this QAPP.

Benthic surveys conducted by Reef Check Washington in 2021 and 2022 at 13 of these study sites show some similarities among regions in the Salish Sea based on the invertebrate and kelp communities and substrate relief (Figure 2; Appendix E). Certain regions, such as Central Puget Sound, demonstrate similar conditions across sites, whereas many other areas (i.e. North Puget Sound) show little consistency in benthic community structure. Investigating these nuances within the different regions of the Salish Sea will improve our understanding of the specific conditions that affect bull kelp, and indicate sites of interest to be targeted for more intensive surveying.

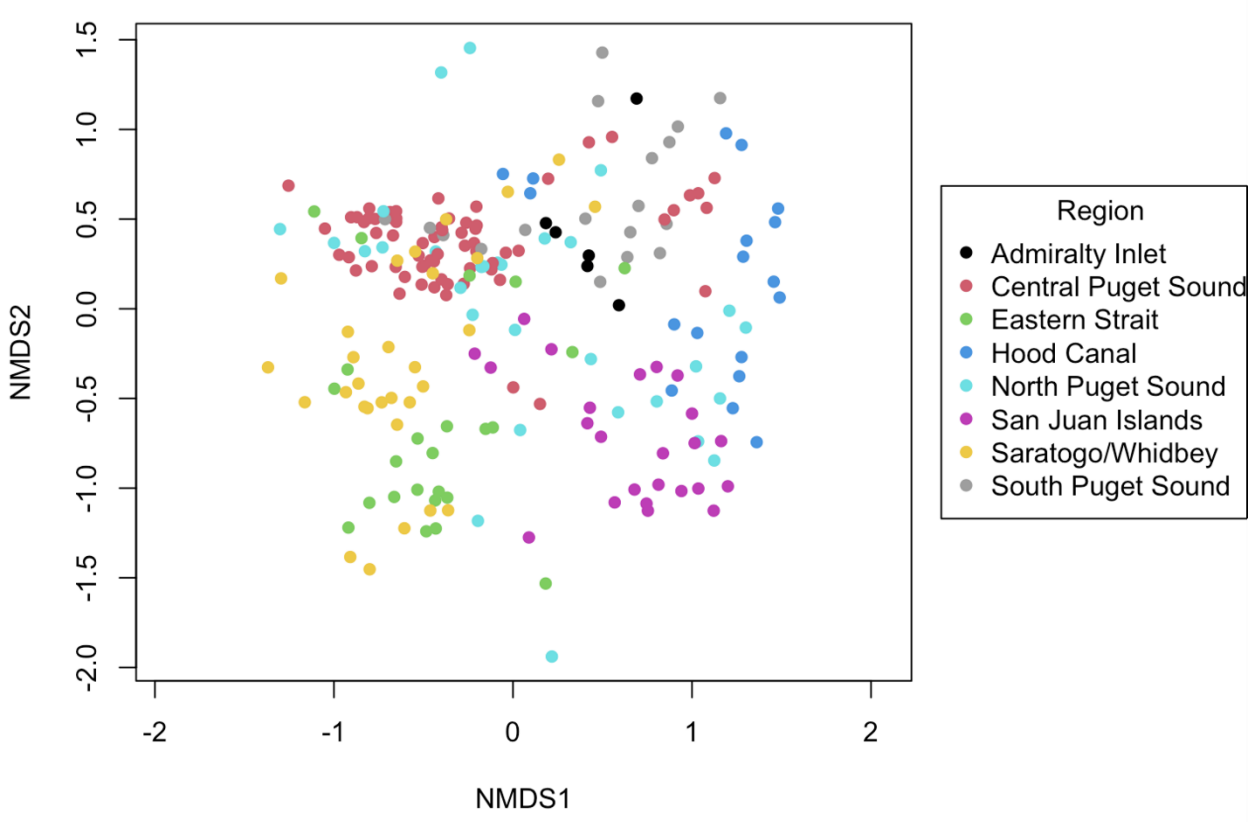

Figure 2. Non-metric multidimensional scaling (NMDS) plot demonstrating similarities among benthic communities within the same region of the Salish Sea, as observed by Reef Check Washington. Points closer together have more similar benthic communities.

3.2.3 Parameters of interest and potential sources

This QAPP is focused on subtidal environmental conditions within and around existing floating kelp beds, or in locations where floating kelp was previously present. The parameters of interest are:

- Density and distribution of indicator species (see Appendix A) for both algae and invertebrates.
- Characterization of reef substrate, including substrate type (bedrock, sand, cobble, etc.), relief, and cover (organisms, if any, attached to substrate).
- Presence of rare and endangered species including pinto abalone (*Haliotis kamtschatkana*) and sunflower stars (*Pycnopodia helianthoides*).
- Presence of invasive species including wireweed (*Sargassum muticum*).

3.2.4 Regulatory criteria or standards

Not Applicable. Does not assess compliance or regulatory criteria.

3.3 Water quality impairment studies

Not Applicable.

3.4 Effectiveness monitoring studies

Not Applicable.

4.0 Project Description

4.1 Project goals

The overarching goal of this project is to advance our understanding of the environmental factors that are associated with floating kelp loss and those associated with floating kelp resilience. Specific goals for the portion of our project that falls within the scope of this QAPP include:

- Synthesis of existing monitoring data (see section 3.2.2) from sites across the Salish Sea to identify gaps in our knowledge about the subtidal communities in areas with persisting, declining, and fully lost bull kelp.
- Once data gaps are identified, conduct seasonal (winter, spring, summer, and fall) field surveys to track the presence and density of indicator species for both algae and invertebrates across sites with persisting, declining, and fully lost bull kelp.

4.2 Project objectives

Objectives for the portion of our project that falls within the scope of this QAPP include:

- Complete synthesis of existing data from citizen science field surveys (Reef Check Washington).
- Complete initial assessment of benthic conditions at all 15 sites across the Salish Sea. Based on this analysis, select a subset of core sites at which monthly dive surveys will be conducted in the first year of this project to capture fine-scale trends and conditions. Results from these first-year surveys will inform the frequency and level of detail of benthic surveys in year two.
- Conduct analyses to summarize patterns in the collected data and compare conditions for bull kelp across study sites.
- Conduct analyses to identify correlations between benthic surveys and local environmental data, which is collected in 2024 as part of this project. (Environmental data collection is covered under a separate QAPP.)

4.3 Information needed and sources.

Sources of existing data to be assembled, and all new data to be collected, that will address project objectives are as followed:

Existing Data

Reef Check Washington survey data

- Sites: Blake Island South, Burrows Lighthouse, Deadman's Bay, Derelict Conveyor, Devils Head, Ebey's Landing, Edmonds Shell Creek, Foulweather Bluff, Goby Garden, Jefferson Head, Ketron Island, Lincoln Park, Lowell Point, Magnolia, McCurdy Point, North Beach, Partridge Point, Point Caution, Point Vashon, Point Whitehorn, Pulali Point, Reuben Tarte, Rosario Head, Seattle Waterfront, Smallpox Bay, South Hat Island, Squaxin Island, Sund Rock, Wing Point
- Timeline: 2021 and 2022 summer surveys
- Variables: Kelp (canopy and understory), invertebrates, uniform point count (substrate survey), fish, invasive species (presence and absence)
- Summary or overview

New Data

- Initial benthic surveys will be done at the network of 15 project sites. Data collection will be initiated once this QAPP is approved and continue through the end of 2025.
- Additional benthic surveys will take place at a core group of sites (to be determined by initial benthic surveys and existing data). These surveys will happen more frequently to capture seasonal trends. For example, these core sites may be monitored for the appearance of juvenile bull kelp sporophytes.

4.4 Tasks required

- Obtain data from Reef Check Washington surveys from 2021 and 2022.
- Complete a multivariate analysis to determine if there are any data gaps that we can fill with future surveys. This analysis and the questions that arise from it will also help inform our selection of core sites.
- Before starting field surveys, all divers must complete necessary University of Washington paperwork and evaluations. Divers must also complete the UW Motorboat Operator Training Course for use of UW boats at shore-inaccessible dive sites.
- Complete initial dive surveys at all 15 sites, including substrate and indicator species surveys.
- For core sites selected for more frequent surveys, complete all dive surveys (see specifics section: 8.0).
- While in the field, divers will verify survey data for legibility and completeness before securely storing and transporting datasheets back to the lab or office. This ensures data will be easily transferable to digital format. Any videos/photos taken in the field will be labeled and uploaded to a shared drive by site and survey type.
- Once all dives are complete and divers return to shore, copy and store all data sheets. Store digital copies in a shared drive.

- Compile surveys from each site into a master data sheet by survey type and conduct a quality assurance and quality control (QA/QC) check of the data to ensure no errors.
- Analyze and interpret the data.
- Write the final report.

4.5 Systematic planning process

Bi-weekly team meetings have already been initiated for planning purposes. Additional meetings with sub-groups on a weekly basis have already been initiated for planning and coordination purposes. These meetings include representatives from the entire project coalition.

5.0 Organization and Schedule

5.1 Key individuals and their responsibilities

Table 1 lists the contact information, affiliations, and responsibilities of those who will be involved in this project.

Table 1. Organization of project staff and responsibilities.

Staff	Title	Responsibilities
Megan Dethier, Director, UW-Friday Harbor Labs Email: mdethier@uw.edu Phone: 206-616-0764	Project Manager/ Principal Investigator	Clarifies scope of the project. Provides internal review of the QAPP and approves the final QAPP. Contributor to semi-annual reports and final reports. Monitors budget.
Helen Berry WA DNR Phone: 360-902-1030	Project Manager	Clarifies scope of the project. Provides internal review of the QAPP and approves the final QAPP. Contributor to semi-annual reports and final reports.
Ande Fieber Friday Harbor Labs Email: amfieber@gmail.com Phone: 408-250-9278	Field Assistant	Writes the QAPP. Oversees field sampling and surveys. Conducts QA review of data, analyzes and interprets data. Contributor to reports.
Rebecca Hansen Friday Harbor Labs Email: rghansen@zoology.ubc.ca Phone: 778-678-5036	Field Assistant	Writes the QAPP. Oversees field sampling and surveys. Conducts QA review of data, analyzes and interprets data. Contributor to reports.
Kindall Murie Friday Harbor Labs Email: kmurie@uw.edu Phone: 208-890-9882	Field Assistant	Writes the QAPP. Oversees field sampling and surveys. Conducts QA review of data, analyzes and interprets data. Contributor to reports.
Ken Nelson **Department of Ecology** Phone: 360-522-2722	NEP Quality Coordinator	Reviews and approves the draft QAPP and the final QAPP.

5.2 Special training and certifications

- **Megan Dethier**, PhD: Megan is the Director of Friday Harbor laboratories and has over 45 years of experience as a shoreline ecologist of the Pacific Northwest. She has worked with the National Park Service and various Washington agencies designing shoreline mapping and monitoring programs. Her current research efforts are mostly focused in the Salish Sea, investigating the linkage between physical features of shoreline habitats and their biota, and the effects of human impacts (such as shoreline armoring) on this linkage.
- **Helen Berry,** PhD: Helen has over 25 years of experience conducting various monitoring activities within the nearshore environment and managing projects focused on monitoring, ecosystem indicators, and focused research studies. Small Motorboat operator, Motorboat Operator Training Course (MOTC) certified.
- **Kindall Murie**: Ph.D. Candidate, University of Washington, Department of Biology. AAUS Scientific/Rescue Diver: 500 dives (200 surveying kelp forest ecosystems), NAUI Rescue Diver, UW diver- check out dive (8/2020), Washington State Boating license, The Motorboat Operator Training Course (MOTC), Reef Check Volunteer Survey Diver (CA, WA). She has deployed temperature, dissolved oxygen, pH, and conductivity sensors for 6 years in both California and Washington kelp forests.
- **Ande Fieber:** M.S. in Marine Biology from Humboldt State University, graduated spring 2020. AAUS Scientific Diver: 200 cold water dives. AAUS Scientific/Rescue Diver, UW diver-check out dive (01/2024), Washington State Boating license (02/2024), Motorboat Operator Training Course (03/2024), Reef Check Volunteer Survey Diver (WA).
- **Rebecca Hansen:** M.S. in Zoology at the University of British Columbia (Vancouver, BC, Canada), Canadian Association for Underwater Science-accredited Scientific Diver (CAUSS)-28 dives, PADI Rescue Diver, UW diver- check out dive (01/2024), Washington State Boating license – (02/2024), The Motorboat Operator Training Course (03/2024).

All field personnel will have a valid US Driver's license.

5.3 Organization chart

See Table 1 for organization of project staff and responsibilities.

5.4 Proposed project schedule

Table 2. Project completion schedule.

Task	Due date	Lead staff
Field Work – Year 1 (Initial surveys, core sites)	February - December 2024	Kindall Murie, Ande Fieber, Rebecca Hansen

Task	Due date	Lead staff
Field Work – Year 2 (Core sites, any additional surveys needed after Year 1)	January - August 2025	Kindall Murie, Ande Fieber, Rebecca Hansen
Data Analysis	January - December 2025	Kindall Murie, Ande Fieber, Rebecca Hansen
Write Final Report	June - December 2025	Kindall Murie, Ande Fieber, Rebecca Hansen
Review Final Report	January - April 2026	Megan Dethier, Helen Berry

5.5 Budget and funding

Funding for this project comes from the Habitat Strategic Initiative, a multi-agency effort within Washington State described here: https://pugetsoundestuary.wa.gov/habitat-strategic-initiative/. The ultimate source of this funding is federal, through the Environmental Protection Agency. The portion of the research covered by this QAPP is coming to the Washington Department of Natural Resources and then transferred to University of Washington via an Interagency Agreement (#93-106108).

The research covered by this QAPP is entirely composed of field work; no lab analyses are included. Table 5 shows the planned expenditure of these funds into broad categories.

Table 3. Project budget and funding.

Cost Category	Cost ($)
Salaries and benefits	211,492
Supplies	20,000
Travel and other	13,000
Contracts	42,000
UW Overhead	74,488

Budget elements are detailed below:

- **Salaries and benefits:** Most of the budget will be spent on a team of divers. We will employ at least 2 full-time research scientist divers (AAUS and UW certified) for two years, plus a graduate student diver and additional part-time divers and boat drivers as needed.
- **Supplies:** This budget is largely for purchasing and maintaining dive gear for the team, along with dive fees, boating supplies (extra anchor, gas cans), supplies needed for underwater surveys, and diverse underwater sensors.
- **Travel:** Because the target sites are scattered around the Salish Sea, substantial travel funds are needed to cover mileage and ferry passes, and lodging and food per diem for divers when they are away from home.

- **Contract:** This budget covers boat rentals (and sometimes boat drivers) for sites where it is not feasible to trailer FHL boats. Because diving will happen year-round for 2 years, and monthly at some sites, these rental costs will accumulate.

6.0 Quality Objectives

6.1 Data quality objectives

The main data quality objective (DQO) for this project is to conduct high-quality benthic surveys at 15 sites in the Salish Sea, which provide detailed information about the subtidal habitat and condition of canopy-forming kelps in Washington.

The DQO are met when field technicians:

- Perform subtidal kelp forest surveys in the target months for each site. Target months are based on current, tidal, and kelp life cycle predictions for each site.
- Return fully completed and verified datasheets and photos from the field and upload to the shared drive.
- QA/QC all survey data, and back up all raw and working files.
- Write up and submit final reports.

6.2 Measurement quality objectives

This project does not involve laboratory analysis; however, the measurement quality objectives (MQO) below are used to ensure precision and reduce bias among diver observations.

6.2.1 Targets for precision, bias, and sensitivity

6.2.1.1 Precision & Bias

To maintain objectivity and ensure the integrity of the collected data, all divers undergo rigorous training in survey methodologies and practice standardization. To ensure this, prior to collecting data, divers compare data from replicate transects of each type as part of their training. The resulting data from each diver must be within a 10% buffer of the lead diver's data in order for the new diver to be signed off on collecting data in that transect type. This calibration training is required for all divers. Divers will also use underwater cameras to gather photos and/or video of uncertain data points that can later be verified by other divers. These efforts ensure that the information gathered is cohesive with the study design, accurate, and unbiased, contributing to a reliable dataset.

6.2.1.3 Sensitivity

Not applicable. This study does not involve any collection of or laboratory analysis of substances (i.e. pollutants or contaminants). Standard equipment used for this project (transect tapes, quadrats) is not susceptible to changes in sensitivity (i.e. cannot be calibrated).

6.2.2 Targets for comparability, representativeness, and completeness

6.2.2.1 Comparability

All survey procedures are based on other well established kelp monitoring programs (see Section 8.2). Specifically, we are modifying the Reef Check Washington Student Guide and PISCO protocols for our kelp forest sampling protocols. Data will be comparable between both methodologies. All decisions and changes are agreed on by the team prior to data collection.

6.2.2.2 Representativeness

Transects for invertebrates, algae, and substrate surveys are replicated within each site as much as possible (depending on the allowable length of the dive, number of divers, etc.). Transects are stratified across a depth gradient of the reef, which ensures that samples are representative of the study site, and are placed greater than 5m apart from one another. As much as possible, surveys will be conducted throughout different seasons to get a better understanding of seasonal variability and patterns that could be unique to each site. Sampling is conducted during daylight hours at least one hour after sunrise and one hour before sunset to reduce variability caused by the nocturnal behavior of some species. Notes are taken on factors such as sea state, underwater visibility, and light conditions in order to flag observations should any of these environmental factors be out of the ordinary.

6.2.2.3 Completeness

The completeness objective for this study is that 95% of all collected data meet measurement quality objectives. There is no attainment objective established given the safety considerations specific to dive surveys. We make all efforts possible to complete all sampling every month to avoid gaps in the data record.

Reasons why sampling may be canceled:

- Severe weather that precludes vessels from embarking. To mitigate this, we will schedule around predicted weather windows and identify backup dates.
- Malfunctioning scuba equipment. To minimize this risk, we maintain our personal equipment, and make sure to test it thoroughly before each dive.
- Measurement/data quality objectives cannot be met; for example, divers may only complete a partial survey along a given transect. To minimize this, we regularly assess survey procedures to ensure all surveys are conducted correctly, plan dives

appropriately to achieve the desired number of survey replicates, and verify all datasheets for completeness.

6.3 Acceptance criteria for quality of existing data

Data received from Reef Check was QA/QC by their organization prior to our analysis.

6.4 Model quality objectives

Not Applicable

7.0 Study Design

7.1 Study boundaries

In general terms, this study aims to gain an understanding of 'what is happening on the benthos' in areas and depths appropriate for bull kelp by surveying these communities within the Washington State portion of the Salish Sea. In practice, the work to be conducted for this study will be focused on the 15 sites shown in Figure 1 that are distributed throughout this broader study area.

A portion of this project involves the compilation of existing data within the study area. This existing data has been collected in the vicinity of the 15 sites (Figure 1), but in some cases the existing data originates from additional sites within the study area.

7.2 Field data collection

The scope of this QAPP includes the collection of environmental survey data of benthic communities. This data collection will take place at the 15 project sites mapped in Figure 1.

7.2.1 Sampling locations and frequency

See section 3.2 for field site locations. Each site will have biological density data collected based on modified Reef Check and PICSO kelp forest protocols for each sampling period.

All 15 sites will receive an initial survey to characterize the reef and understand any logistical challenges of accessing/surveying the site (current-sensitive, boat access only, etc.). Using these initial surveys, monitoring data from DNR describing long-term kelp trends (declining, stable, increasing), other existing data (i.e. Reef Check surveys), and the region in which the site is found, a subset of core sites (5-6) will be designated. These core sites will be selected in a balanced design that includes a) equal numbers of resilient and declining kelp sites, and b) representatives from the entire study region to capture spatial variation throughout the Salish Sea.

7.2.2 Field parameters and laboratory analytes to be measured

Benthic surveys will be designed using the Reef Check Washington survey protocols as a model for characterizing substrate and kelp forest communities. With a focus on bull kelp and the species (see Appendix A) and conditions that influence it, these protocols will be modified to capture relevant data (see Appendix B for sample datasheet). Using a combination of multiple survey methods and tools, divers will gather data focusing primarily on:

- Bull kelp presence, abundance, and condition (within core sites only)
- Presence, abundance, and diversity of other turf- and understory-forming algae
- Presence and abundance of invasive algae (i.e. *Sargassum muticum*)
- Abundance and diversity of benthic invertebrates, with particular focus on invertebrates that have ecological relationships with bull kelp within their life histories

- Substrate type, relief, and cover (by algae and/or invertebrates)
- Additional observations of organisms whose presence or absence may influence bull kelp survival or condition (i.e. wolf eels or other relevant predators)
- Additional observations of other parameters identified during initial surveys as important additions to the above data priorities

Reef Check Washington protocols are a strong model for understanding the benthic conditions experienced by bull kelp, but certain parameters are not relevant to our study. The following elements will be removed from the Reef Check protocols as they are adapted to our work:

- **Fish surveys.** While many fish species utilize bull kelp at various stages in their life cycle, they are unlikely to influence kelp either directly or indirectly.
- **Certain invertebrate species.** Many common invertebrates, while often present in local reef systems, do not have an ecological connection with bull kelp. Our species list (see Appendix A) has removed a number of species who do not consume, compete with, or otherwise influence kelp abundance or condition.

Additionally, to capture more information related specifically to bull kelp habitat, the following elements will be added to our survey protocols:

- **Quadrat surveys.** As an added element to the Uniform Point Count survey type, divers will deploy a 0.5m quadrat at 5m increments and document percent cover of algae, invertebrates, and substrate. This survey will provide additional information about the composition of the benthos at each site.
- **Kelp condition surveys.** At core sites only, divers will randomly select 10 bull kelp individuals and record their height (<1, midwater, or canopy) and minimum stipe diameter. These data will provide a 'snapshot' of the kelp population at each site and will be replicated through time at each core site to help us understand the progression of kelp through its sporophyte (macroscopic) stage.

7.3 Modeling and analysis design

Not Applicable

7.3.1 Analytical framework

Not Applicable

7.3.2 Model setup and data needs

Not Applicable

7.4 Assumptions of study design

This study assumes that all divers are trained to accurately identify, count and size organisms underwater while conducting surveys of standardized size and type (see section 6.2.2.2). Rigorous training and verification of survey accuracy ensures that this assumption is met and that divers who do not reach our standards are not permitted to contribute data.

7.5 Possible challenges and contingencies

7.5.1 Logistical problems

Some sites have limited access due to private or tribal property. We work to develop relationships with residents and tribal agencies to access sites. Additionally, many sites are accessible by boat only; all divers are therefore trained in boat operation through the UW Motorboat Operator Training Course.

7.5.2 Practical constraints

Kelp beds are typically in areas of strong currents and wave action. All divers are trained to assess the conditions prior to each dive and make sure that they are capable and knowledgeable about the limits that come with diving at each site. All divers are expected to speak up and communicate if they do not feel safe beginning or continuing the planned dive. Additionally, even in optimal dive conditions, surface conditions may prohibit safe boating to access survey sites. Boat operators are also expected to communicate any concerns and may elect to cancel any outing if predicted or real-time conditions become unsafe. Surveys will, as much as possible, be scheduled during optimal current and weather conditions, with contingency dates planned into the dive schedule to account for the likelihood of occasional poor and/or unsafe diving or boating conditions.

7.5.3 Schedule limitations

The above-described problems and constraints may limit our ability to survey each site with the proposed frequency and sampling effort. Whenever possible, contingency plans will be added to our schedule to make up any dives canceled by weather or other obstacles.

8.0 Field Procedures

8.1 Invasive species evaluation

Study sites are not located within areas of extreme concern, as listed on the website of the Department of Ecology (Data - Washington State Department of Ecology). The precautions and procedures outlined in EAP070 version 2.3 will be followed prior to and after all field activities.

This project does not require the collection or transportation of any organisms. Dive gear could potentially act as carriers of invasive species. Good practice to maintain dive gear is to rinse/soak all gear, including survey tools, in freshwater after each dive day. This will also address the potential risk of transporting invasive marine species from site to site. Watercraft will also be cleaned before and after use and checked for aquatic invasives prior to field efforts.

8.2 Measurement and sampling procedures

Survey protocols will be modeled after Reef Check Washington and PISCO Kelp Forest Sampling methods. Surveys will employ a variety of methods to gather benthic community data, including:

- Swath surveys of a standardized area
- Quadrat surveys at standardized intervals
- Photo and/or video capture (for site location details, species verification, etc.)
- Kelp condition surveys (at core sites only)

Divers will survey each site for the determined parameters (see Section 7.2.2) and record all data on waterproof datasheets designed for this study (see Appendix B) and enclosed in sturdy dive slates. Divers will use transect tapes (deployed to 30m lengths) and 0.5m quadrats for standard surveys at all sites, and will use calipers to measure minimum stipe diameter at core sites only.

For surveys occurring along a transect line, divers may conduct multiple passes along the same line to gather different data. For example, the diver may conduct an algae survey on her first pass, then return along the same line while conducting an invertebrate survey. This method ensures efficiency and data quality, as the diver is focused on only one survey type at a time.

8.3 Containers, preservation methods, holding times

Not Applicable

8.4 Equipment decontamination

Not Applicable

8.5 Sample ID

Not Applicable

8.6 Chain of custody

Not Applicable

8.7 Field log requirements

Field staff will use a field data sheet or water-resistant field notebook to document each survey event. A correction is made to the sheet or notebook with a single-line strikethrough, initials, and correction date. Staff will verify forms or notebook for missing or anomalous measurements before leaving each site, and later enter field logs into digital datasheets to be stored in a Google drive, which is shared with DNR. The following information will be recorded for each field event:

- Field staff.
- Date, time, location, and surveys taking place. This includes number of transects (or other survey elements) completed and their depth profiles.
- Weather and water conditions (current, calm, mild, etc.).
- Notable site-relevant observations.
- Circumstances that might affect or bias results.

At the end of each field day, the field staff are in charge of making sure all survey data sheets are checked, collected, transcribed, and stored properly within the shared drive.

8.8 Other activities

Other activities to maintain field data collection, processing, and consistency include:

- Field staff training.
- Dive briefing and debriefing (especially when dive staff are new to a site), including pre-dive safety checks and gear/equipment checks (see Appendix D for standard dive safety protocols).
- Equipment maintenance (especially pertaining to personal dive gear), which generally consists of rinsing with freshwater after each dive and checking over equipment for any parts that may be weakened or broken.
- Storing and maintaining data logs, including dive logs (see Appendix C)

9.0 Laboratory Procedures

9.1 Lab procedures table

Not applicable

9.2 Sample preparation method(s)

Not applicable

9.3 Special method requirements

Not applicable

9.4 Laboratories accredited for methods

Not applicable

10.0 Quality Control Procedures

The project's quality control (QC) procedures consist of three parts:

1. Diver training in species identification and survey methods
2. Adherence to the survey procedures, including photographing anomalous or confusing species/data points for later verification
3. Assessing the quality and completeness of each datasheet immediately following each survey dive

These procedures are used to maximize the quality of the collected data and to minimize inaccuracies or mistakes associated with data collection and processing.

Training

All divers will complete proper training by mastering species identification and standard survey protocols for each survey type. Divers will also complete training dives, during which multiple divers will conduct the same survey, then compare results to verify consistency and accuracy. If needed, newer divers may also 'test' their survey skills by completing the same transect as a more experienced diver and gathering the same data within a 10% buffer. Following sufficient survey training, divers will then be permitted to collect data for the project.

Data Collection

Survey methods are designed to ensure diver safety (including buddy proximity), accurate data collection of one data type (i.e. algae or invertebrates) at a time, and contingency for unclear or confusing data points (i.e. unable to identify a species). Whenever possible, replicate transects will be completed at each site to help mitigate the impact of accidental inaccuracies in any single survey. All surveyors must follow the methods outlined in the established protocols (see

section 8.2 for protocol overview). The following items are included in the survey protocol to reduce sampling error and bias:

- Standardized site selection and transect deployment procedures
- Standardized list of species and/or functional groups to document, as listed on each datasheet
- Minimum size requirements for all invertebrate and algal species surveyed
- Grouping of species or genera with similar morphological traits to reduce the likelihood of misidentification
- Employment of standardized data notation procedures on datasheets

Field Data Verification

Immediately following each dive, each team member must review their datasheet for completeness and legibility. The Data Captain (specified prior to each trip) verifies the collection of each sheet and discusses any potential outliers with the team member. If a consensus on any data cannot be reached, the team leader will flag the datasheet for further review by the whole team at group meetings.

Finalizing Data

As surveys are completed, a designated team member will combine all data into a master datasheet for each survey type and remove erroneous data before submitting into the shared drive. All datasheets will be archived in digital and hard copy formats.

10.1 Table of field and laboratory quality control

Not Applicable

10.2 Corrective action processes

If there are concerns about data while the team is surveying, they will start again and use a new datasheet or take photos of species for later identification. If there are concerns during analysis, the team will discuss this concern to determine if the data are likely to be real or the result of an error. Data points will be removed if errors cause data to be unreliable.

11.0 Data Management Procedures

11.1 Data recording and reporting requirements

Data are recorded on underwater paper and datasheets are collected in the field after each survey and scanned into digital copies. Hard copies are retained, and the scans are uploaded to the shared Google drive. Data are entered from these scans into the master data sheets that

are also stored in the drive. All drive files will also be saved to a portable hard drive labeled after this project.

11.2 Laboratory data package requirements

Not Applicable

11.3 Electronic transfer requirements

Not Applicable

11.4 Data upload procedures

All compatible water quality data will be submitted to EPA's WQX annually. See Section 11.1 for data being uploaded to Google drive.

11.5 Model information management

Not Applicable

12.0 Audits and Reports

12.1 Audits

Audits are not anticipated for this project. Progress is shared and discussed at weekly staff meetings.

12.2 Responsible personnel

Megan Dethier (PI) is responsible for final analysis and reporting review, while the research assistants are responsible for collecting, storing, and QA/QC of all data, and writing and finalizing reports.

12.3 Frequency and distribution of reports

Protocols and this QAPP will be reviewed annually after the survey season has ended. If the review among divers and PI identifies a need for a significant change in protocols, schedule, or site locations, an addendum to this QAPP will be submitted. Reports to the funding agency will include brief information on each of the following areas:

- A comparison of actual accomplishments to the outputs/outcomes established in the assistance agreement work plan for the period
- Results of the subtidal kelp forest surveys
- The reasons for slippages if established outputs/outcomes were not met
- Additional pertinent information, including when appropriate, analysis and information of cost overruns or high unit costs
- Recommendations for any modification to the protocols and species list

A final report will be submitted at the end of the project (no longer than 60 days after the termination of the grant agreement). This report will contain the same information as the interim reports, but will cover the entire project period.

12.4 Responsibility for reports

All members will work as a team to generate annual reports and Megan Dethier will give the final approval before submission. Annual updates are to be shared in written reports and presentations.

13.0 Data Verification

13.1 Field data verification, requirements, and responsibilities

The following QA/QC field procedures are completed by each dive team and then reviewed by the Data Captain before leaving the field site:

- Confirm that all metadata (site name, transect location, depth, heading, surveyor name) is filled out properly.
- Check that species codes are legible, and that counts (if applicable) are totaled correctly.
- Verify any modified or nullified data points as such.
- Confirm that all relevant (for the survey type) sections of the datasheet have been completed fully.
- Add slashes to zeros and sevens to make data easier to read.

The Data Captain then confirms all expected datasheets are collected and properly stored for transportation back to the lab or office. As data are entered, divers may be contacted directly to confirm any questions (e.g. illegibility) that may arise.

13.2 Laboratory data verification

Not Applicable

13.3 Validation requirements, if necessary

Not Applicable

13.4 Model quality assessment

Not Applicable

14.0 Data Quality (Usability) Assessment

14.1 Process for determining project objectives were met

The Project Manager will evaluate if the project has met the original objectives by assessing:

- Whether data were collected in a manner consistent with the study design, methods, and procedures described in the final approved QAPP.
- If enough of the data are deemed usable after verification.

Objectives will likely be met if most sites are surveyed with the intended frequency and the data are collected and controlled to ensure data quality standards.

14.2 Treatment of non-detects

Not Applicable

14.3 Data analysis and presentation methods

Survey data will be analyzed in a variety of ways to identify spatial patterns (for standard sites, sampled quarterly) and temporal trends (for core sites, sampled monthly) in species distributions, population dynamics, and benthic community structure of kelp forests. All analyses will take place in the R environment.

Exact analysis methods will depend upon the structure of the datasets, but may include:

- Summary statistics and data exploration methods (i.e. histograms, boxplots, etc.)
- Regression analysis
- Analyses of variance (i.e. repeated-measures ANOVA)
- Ordinations (NMDS, PCoA)

14.4 Sampling design evaluation

The sample design is evaluated based on the success of site access, survey completion, and data collection. If meaningful conclusions can be drawn from the data, the sample design will be considered effective.

14.5 Documentation of assessment

Reported as part of the final data synthesis and project summary report.

15.0 References

Berry, H.D., J.R. Harper, T.F. Mumford, Jr., B.E. Bookheim, A.T. Sewell, and L.J. Tamayo (2001). The Washington State ShoreZone Inventory User's Manual. Nearshore Habitat Program, Washington State Department of Natural Resources, Olympia, WA.

Berry, H.D. (2017). Assessment of bull kelp at Squaxin Island in 2013, 2014 and 2016. Nearshore Habitat Program. Washington State Department of Natural Resources, Olympia, WA.

Berry, H. D., Calloway, M. D., & Ledbetter, J. (2019). Bull kelp monitoring in south Puget Sound in 2017 and 2018. Washington State Department of Natural Resources, Aquatic Resources Division,Nearshore Habitat Program, Olympia, WA.

Berry, H. D., Mumford, T. F., Christiaen, B., Dowty, P., Calloway, M., Ferrier, L., Grossman, E. E., & VanArendonk, N. R. (2021). Long-term changes in kelp forests in an inner basin of the Salish Sea. *PLOS ONE, 16*(2). https://doi.org/10.1371/journal.pone.0229703

Calloway, M., Oster, D., Berry, H., Mumford, T., Naar, N., Peabody, B., Hart, L., Tonnes, D., Copps, S., Selleck, J., Allen, B., & Toft, J. (2020). Puget Sound kelp conservation and recovery plan. Prepared for NOAA-NMFS, Seattle, WA.

McClure, T., H. Berry and P. Dowty, in prep. Dynamics of Temperature and Kelp Declines at Squaxin Island: Analysis of 2021-2022 monitoring data and implications for South Puget Sound kelp communities. Washington Department of Natural Resources, Olympia, WA.

Weigel, B.L., S.L. Small, H.D. Berry and M.N. Dethier (2023). Effects of temperature and nutrients on microscopic stages of the bull kelp (*Nereocystic luetkeana*, Phaeophyceae). *Journal of Phycology, 59*(5). https://doi.org/10.1111/jpy.13366

16.0 Appendices

Appendix B. Dive survey datasheets

Table A - 1. Indicator species that may be surveyed.

Functional group	Taxon	Common name	Survey
Canopy brown algae	*Nereocystis luetkeana*	Bull kelp	Swath
Midwater canopy or understory brown algae	*Agarum clathratum; Neoagarum fimbriatum*	Sieve kelp	Swath
	Alaria marginata	Winged kelp	Swath
	Costaria costata	5-ribbed kelp	Swath
	Cymathere triplicata	3-ribbed kelp	Swath
	Desmarestia spp.	Acid weed	Swath
	Egregia menziesii	Feather boa kelp	Swath
	Laminaria spp.	Laminaria	Swath
	Pterygophora californica	Woody kelp	Swath
	Saccharina latissima	Sugar kelp	Swath
	Sargassum muticum	Wire weed	Swath
Turf-forming red algae	*Cryptopleura ruprechtiana*	Ruffled red seaweed	UPC
	Polyneura latissima	Crisscross red seaweed	UPC
Articulated coralline algae	*Calliarthron tuberculosum*	Coralline algae	UPC
	Bossiella spp.	Coralline algae	UPC
	Corallina spp.	Coralline algae	UPC
Encrusting algae	*Hildenbrandia* spp.	Encrusting red algae	UPC
	Ralfsia spp.	Encrusting brown algae	UPC
	(numerous species)	Crustose coralline algae	UPC
Grazers of kelp	*Calliostoma* spp.	Top snail	Stipe
	Cryptochiton stelleri	Gumboot chiton	Swath
	Haliotis kamtschatkana	Pinto abalone	Swath
	Lacuna spp.	Lacuna snail	Stipe
	Lottia spp.	Limpet	Stipe
	Mesocentrotus franciscanus	Red urchin	Swath
	Pugettia spp.	Kelp crab	Stipe
	Strongylocentrotus purpuratus	Purple urchin	Swath
	Strongylocentrotus droebachiensis	Green/pallid urchin	Swath
Predators of grazers	*Cancer productus*	Red rock crab	Swath
	Leptasterias spp.	Six-rayed star	Swath
	Pisaster ochraceus	Ochre star	Swath
	Pycnopodia helianthoides	Sunflower star	Swath
	Anarrhicthys ocellatus	Wolf eel	Swath
	Enteroctopus dofleini	Giant Pacific octopus	Swath

Appendix B. Dive survey datasheets

HSIL KELP SURVEY - UPC & QUADRAT

Date: _____ Buddy: _____ Transect #: _____

Site: _____ Tender: _____ Target depth: _____

Diver: _____ Time in: _____ Bottom time: _____

UNIFORM POINT COUNT - 0.5m to either side of transect

Meter	Cover	Substrate	Sed. depth	Relief
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				

Cover	
Red algae (turf)	RA
Encrusting red algae	ER
Articulated coralline	AC
Crustose coralline	CC
Green algae	GA
Brown algae holdfast	BA
Sessile invertebrate	SI
Eelgrass (Zostera marina)	ZM
Bare rock	BR
Substrate	
Sand (<0.5cm)	S
Pebble (0.5 - 5cm)	P
Cobble (5cm - 15cm)	C
Rock (15cm - 25cm)	RK
Sm boulder (25cm - 50cm)	SB
Lg boulder (50cm - 1m)	LB
Reef (>1m)	R
Shell hash	SH
Other	O
Sediment depth	
<1cm	0
1-5cm	1
>5cm	2
Relief	
0 - 10cm	0
10cm - 1m	1
1m - 2m	2
>2m	3
Superlayer (SL)	
Mobile invertebrate	MI
Brown algae blade	BB

QUADRATS

Meter	SL (% + code)	(% + code for each group)
5		
10		
15		
20		
25		
30		

Figure B - 1. Datasheet for uniform point count (UPC) and quadrat surveys.

HSIL KELP SURVEY - ALGAE & INVERTS

Date: _____ Buddy: _____ Transect #: _____

Site: _____ Tender: _____ Target depth: _____

Diver: _____ Time in: _____ Bottom time: _____

ALGAE - 1m to either side of transect

Species	Count (tally or #)						Total

Alaria marginata	AM
Agarum/Neoagarum spp.	AS
Costaria costata	CC
Cymathaere triplicata	CT
Desmarestia spp.	DS
Egregia menziesii	EM
Laminaria setchellii	LS
Macrocystis pyrifera	MP
Nereocystis luetkeana	NL
Pterygophora californica	PC
Pleurophycus gardneri	PG
Saccharina/Hedophyllum	SH
Sargassum spp.	SS

Subsample: >50 individuals + >5m, write distance next to count & circle

CORE SURVEY ONLY - NEREOCYSTIS STIPES

m	Height	Diameter	m	Height	Diameter
3			18		
6			21		
9			24		
12			27		
15			30		

Height	
0 - 1 m	1
<1 m - midwater	2
Canopy	3

Diameter in mm at narrowest point

Choose stipe nearest to (m) mark

INVERTEBRATES - 1m to either side of transect

Species	Count (tally or #)						Total

Only count individuals ≥2.5cm

Anarrhicthys ocellatus*	AO
Cancer productus	CP
Cryptochiton stelleri	CS
Fusitriton oregonensis	FO
Haliotus kamtschatkana	HK
Leptasterias spp.	LS
Metacarcinus magister	MM
Octopus/Enteroctopus spp.	OS
Pycnopodia helianthoides	PH
Pisaster ochraceus	PO
Pugettia gracilis	PG
Pugettia producta	PP
M. franciscanus	MF
S. droebachiensis	SD
S. purpuratus	SP

Figure B - 2. Datasheet for algae, bull kelp, and invertebrate surveys.

Appendix C. Dive logs

HSIL DiveLOG

Location codes:												
Burrows Lighthouse (BUR)		Devil's Head (DVL)		Freashwater Bay (FWB)			Mukilteo (MUK)			Salmon Beach (SAL)		
Point Caution (CAU)		Edmonds (EDM)		Lincoln Park (LIP)			North Beach (NOB)			Squaxin Island (SQX)		
Cherry Point (CHP)		Fox Island (FOX)		Magnolia (MAG)			Rich Passage (RCH)			Wing Point (WNG)		
Divers	Boat opr.	Date	Location	Mission	Max. Depth (m)	Bottom Time (m)	Time In	Time Out	Sea State	Vis (m)	Water Temp	Notes
Diver Full Names:												
Mission: Sensor Mgmt., Std. Survey, Core Survey, Training, Other												
Sea State: Calm (C), Moderate (M), Rough (R)												

Figure C - 1. Sample dive log for recording survey activity.

Appendix D. Safety manuals

Please use the links below to navigate to the diving and boating safety manuals used by field staff, as required by the University of Washington.

University of Washington Dive Safety Manual

University of Washington Boating Safety Manual

Appendix E. Analyses of existing data

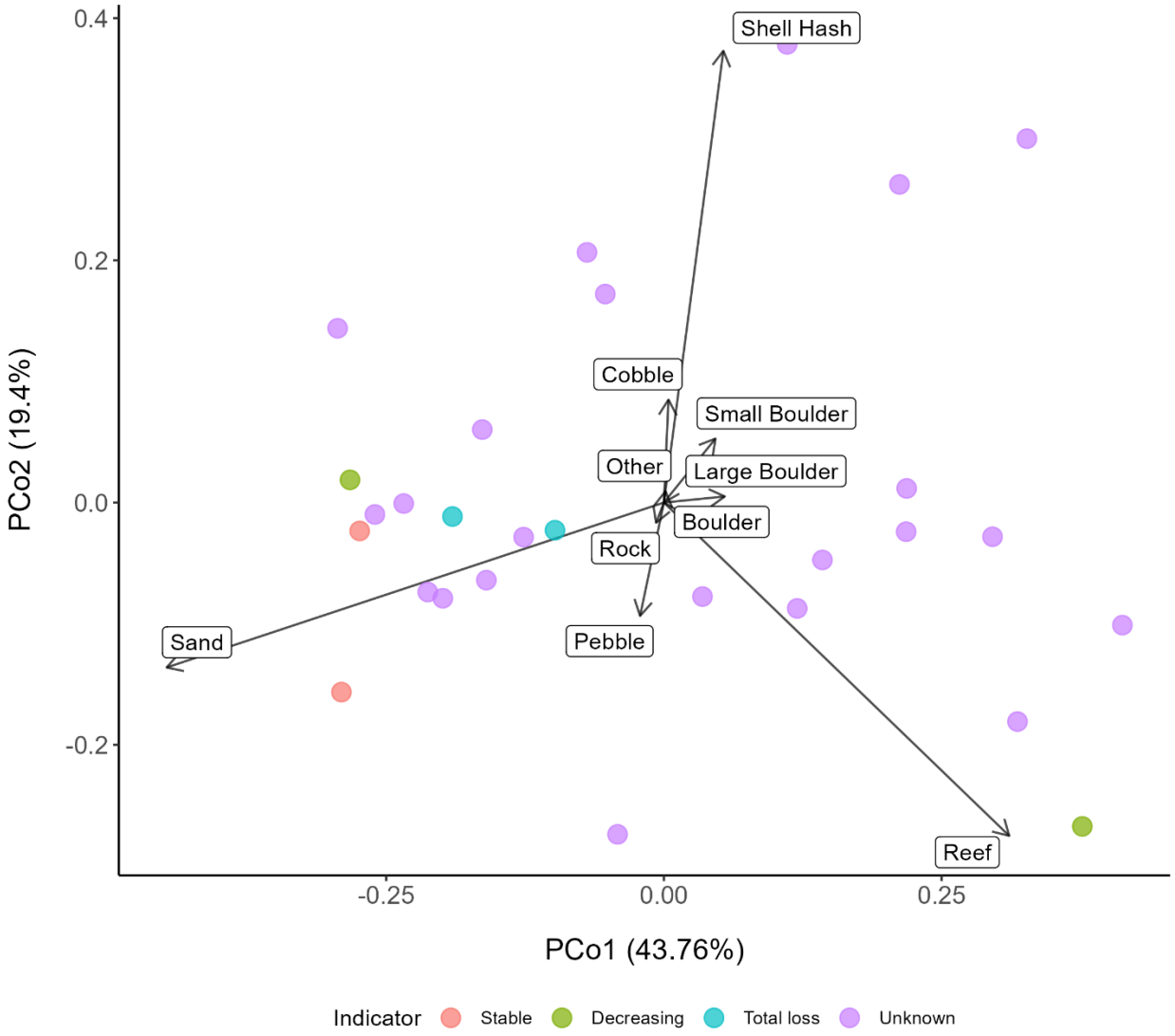

Figure E - 1. Principal coordinates analysis (PCoA) of stable, decreasing, lost, and unknown-status kelp forests in the Salish Sea by substrate type. Data from Reef Check Washington 2022 surveys.

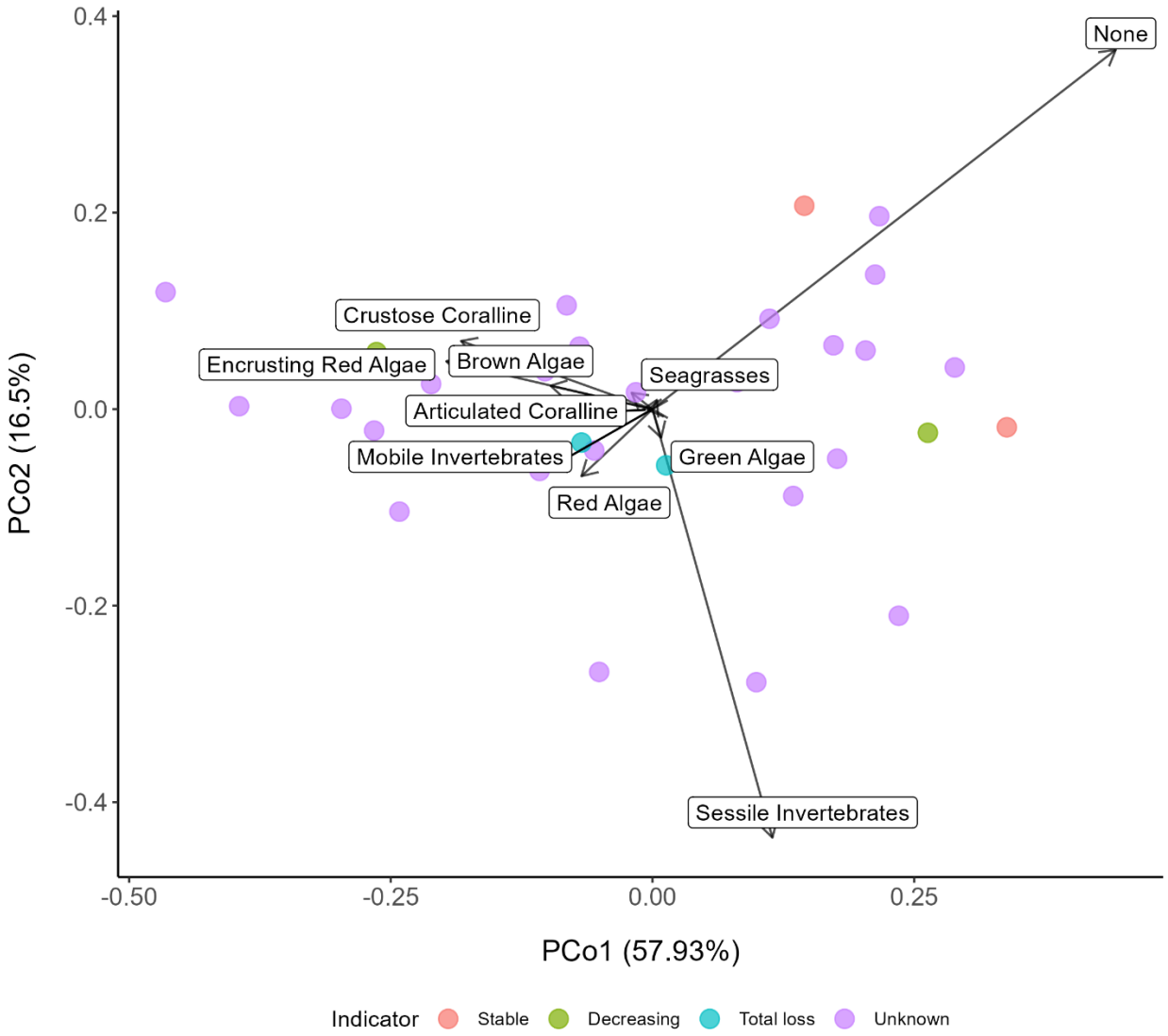

Figure E - 2. PCoA of stable, decreasing, lost, and unknown-status kelp forests in the Salish Sea by cover, or the organism (if any) occupying the reef surface at the survey point. Data from Reef Check Washington 2022 surveys.

Appendix F. Glossaries, acronyms, and abbreviations

Glossary of General Terms

Acronyms and Abbreviations

DQO	Decision Quality Objectives
etc.	et cetera
e.g.	for example
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
et al.	and others
i.e.	in other words
QA	quality assurance
QC	quality control
SOP	standard operating procedures
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife

Units of Measurement

m	meter

Quality Assurance Glossary

Accreditation: A certification process for laboratories, designed to evaluate and document a lab's ability to perform analytical methods and produce acceptable data (Kammin, 2010). For

Ecology, it is defined according to WAC 173-50-040: “Formal recognition by [Ecology] that an environmental laboratory is capable of producing accurate and defensible analytical data.”

Accuracy: The degree to which a measured value agrees with the true value of the measured property. USEPA recommends that this term not be used, and that the terms *precision* and *bias* be used to convey the information associated with the term *accuracy* (USEPA, 2014).

Analyte: An element, ion, compound, or chemical moiety (pH, alkalinity) which is to be determined. The definition can be expanded to include organisms, e.g., fecal coliform, Klebsiella (Kammin, 2010).

Bias: Discrepancy between the expected value of an estimator and the population parameter being estimated (Gilbert, 1987; USEPA, 2014).

Blank: A synthetic sample, free of the analyte(s) of interest. For example, in water analysis, pure water is used for the blank. In chemical analysis, a blank is used to estimate the analytical response to all factors other than the analyte in the sample. In general, blanks are used to assess possible contamination or inadvertent introduction of analyte during various stages of the sampling and analytical process (USGS, 1998).

Calibration: The process of establishing the relationship between the response of a measurement system and the concentration of the parameter being measured (Ecology, 2004).

Check standard: A substance or reference material obtained from a source independent from the source of the calibration standard; used to assess bias for an analytical method. This is an obsolete term, and its use is highly discouraged. See Calibration Verification Standards, Lab Control Samples (LCS), Certified Reference Materials (CRM), and/or spiked blanks. These are all check standards but should be referred to by their actual designator, e.g., CRM, LCS (Kammin, 2010; Ecology, 2004).

Comparability: The degree to which different methods, data sets and/or decisions agree or can be represented as similar; a data quality indicator (USEPA, 2014; USEPA, 2020).

Completeness: The amount of valid data obtained from a project compared to the planned amount. Usually expressed as a percentage. A data quality indicator (USEPA, 2014; USEPA 2020).

Continuing Calibration Verification Standard (CCV): A quality control (QC) sample analyzed with samples to check for acceptable bias in the measurement system. The CCV is usually a midpoint calibration standard that is re-run at an established frequency during the course of an analytical run (Kammin, 2010).

Control chart: A graphical representation of quality control results demonstrating the performance of an aspect of a measurement system (Kammin, 2010; Ecology 2004).

Control limits: Statistical warning and action limits calculated based on control charts. Warning limits are generally set at +/- 2 standard deviations from the mean, action limits at +/- 3 standard deviations from the mean (Kammin, 2010).

Data integrity: A qualitative DQI that evaluates the extent to which a data set contains data that is misrepresented, falsified, or deliberately misleading (Kammin, 2010).

Data quality indicators (DQI): Commonly used measures of acceptability for environmental data. The principal DQIs are precision, bias, representativeness, comparability, completeness, sensitivity, and integrity (USEPA, 2006).

Data quality objectives (DQO): Qualitative and quantitative statements derived from systematic planning processes that clarify study objectives, define the appropriate type of data, and specify tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support decisions (USEPA, 2006).

Data set: A grouping of samples organized by date, time, analyte, etc. (Kammin, 2010).

Data validation: The process of determining that the data satisfy the requirements as defined by the data user (USEPA, 2020). There are various levels of data validation (USEPA, 2009).

Data verification: Examination of a data set for errors or omissions, and assessment of the Data Quality Indicators related to that data set for compliance with acceptance criteria (MQOs). Verification is a detailed quality review of a data set (Ecology, 2004).

Detection limit (limit of detection)**:** The concentration or amount of an analyte which can be determined to a specified level of certainty to be greater than zero (Ecology, 2004).

Duplicate samples: Two samples taken from and representative of the same population, and carried through and steps of the sampling and analytical procedures in an identical manner. Duplicate samples are used to assess variability of all method activities including sampling and analysis (USEPA, 2014).

Field blank: A blank used to obtain information on contamination introduced during sample collection, storage, and transport (Ecology, 2004).

Initial Calibration Verification Standard (ICV): A QC sample prepared independently of calibration standards and analyzed along with the samples to check for acceptable bias in the measurement system. The ICV is analyzed prior to the analysis of any samples (Kammin, 2010).

Laboratory Control Sample (LCS)/LCS duplicate: A sample of known composition prepared using contaminant-free water or an inert solid that is spiked with analytes of interest at the midpoint of the calibration curve or at the level of concern. It is prepared and analyzed in the same batch of regular samples using the same sample preparation method, reagents, and analytical methods employed for regular samples. Monitors a lab's performance for bias and precision (USEPA, 2014).

Matrix spike/Matrix spike duplicate: A QC sample prepared by adding a known amount of the target analyte(s) to an aliquot of a sample to check for bias and precision errors due to interference or matrix effects (Ecology, 2004).

Measurement Quality Objectives (MQOs)**:** Performance or acceptance criteria for individual data quality indicators, usually including precision, bias, sensitivity, completeness, comparability, and representativeness (USEPA, 2006).

Measurement result: A value obtained by performing the procedure described in a method (Ecology, 2004).

Method: A formalized group of procedures and techniques for performing an activity (e.g., sampling, chemical analysis, data analysis), systematically presented in the order in which they are to be executed (USEPA, 2001).

Method blank: A blank prepared to represent the sample matrix, prepared and analyzed with a batch of samples. A method blank will contain all reagents used in the preparation of a sample, and the same preparation process is used for the method blank and samples (Ecology, 2004; Kammin, 2010).

Method Detection Limit (MDL): The minimum measured concentration of a substance that can be reported with 99% confidence that the measured concentration is distinguishable from method blank results (USEPA, 2016). MDL is a measure of the capability of an analytical method of distinguished samples that do not contain a specific analyte from a sample that contains a low concentration of the analyte (USEPA, 2020).

Minimum level: Either the sample concentration equivalent to the lowest calibration point in a method or a multiple of the method detection limit (MDL), whichever is higher. For the purposes of NPDES compliance monitoring, EPA considers the following terms to be synonymous: “quantitation limit,” “reporting limit,” and “minimum level” (40 CFR 136).

Parameter: A specified characteristic of a population or sample. Also, an analyte or grouping of analytes. Benzene and nitrate + nitrite are all parameters (Kammin, 2010; Ecology, 2004).

Population: The hypothetical set of all possible observations of the type being investigated (Ecology, 2004).

Precision: The extent of random variability among replicate measurements of the same property; a data quality indicator (USGS, 1998).

Quality assurance (QA): A set of activities designed to establish and document the reliability and usability of measurement data (Kammin, 2010).

Quality Assurance Project Plan (QAPP): A document that describes the objectives of a project, and the processes and activities necessary to develop data that will support those objectives (Kammin, 2010; Ecology, 2004).

Quality control (QC): The routine application of measurement and statistical procedures to assess the accuracy of measurement data (Ecology, 2004).

Relative Percent Difference (RPD): RPD is commonly used to evaluate precision. The following formula is used:

$$RPD = [Abs(a-b)/((a + b)/2)] * 100\%$$

where "Abs()" is absolute value and a and b are results for the two replicate samples. RPD can be used only with 2 values. Percent Relative Standard Deviation is (%RSD) is used if there are results for more than 2 replicate samples (Ecology, 2004).

Relative Standard Deviation (RSD): A statistic used to evaluate precision in environmental analysis. It is determined in the following manner:

$$RSD = (100\% * s)/x$$

where s is the sample standard deviation and x is the mean of results from more than two replicate samples (Kammin, 2010).

Replicate samples: Two or more samples taken from the environment at the same time and place, using the same protocols. Replicates are used to estimate the random variability of the material sampled (USGS, 1998).

Reporting level: Unless specified otherwise by a regulatory authority or in a discharge permit, results for analytes that meet the identification criteria (i.e., rules for determining qualitative presence/absence of an analyte) are reported down to the concentration of the minimum level established by the laboratory through calibration of the instrument. EPA considers the terms "reporting limit," "quantitation limit," and "minimum level" to be synonymous (40 CFR 136).

Representativeness: The degree to which a sample reflects the population from which it is taken; a data quality indicator (USGS, 1998).

Sample (field): A portion of a population (environmental entity) that is measured and assumed to represent the entire population (USGS, 1998).

Sample (statistical): A finite part or subset of a statistical population (USEPA, 1992).

Sensitivity: In general, denotes the rate at which the analytical response (e.g., absorbance, volume, meter reading) varies with the concentration of the parameter being determined. In a specialized sense, it has the same meaning as the detection limit (Ecology, 2004).

Spiked blank: A specified amount of reagent blank fortified with a known mass of the target analyte(s); usually used to assess the recovery efficiency of the method (USEPA, 2014).

Spiked sample: A sample prepared by adding a known mass of target analyte(s) to a specified amount of matrix sample for which an independent estimate of target analyte(s) concentration

is available. Spiked samples can be used to determine the effect of the matrix on a method's recovery efficiency (USEPA, 2014).

Split sample: A discrete sample subdivided into portions, usually duplicates (Kammin, 2010).

Standard Operating Procedure (SOP): A document which describes in detail a reproducible and repeatable organized activity (Kammin, 2010).

Surrogate: For environmental chemistry, a surrogate is a substance with properties similar to those of the target analyte(s). Surrogates are unlikely to be native to environmental samples. They are added to environmental samples for quality control purposes, to track extraction efficiency and/or measure analyte recovery. Deuterated organic compounds are examples of surrogates commonly used in organic compound analysis (Kammin, 2010).

Systematic planning: A step-wise process which develops a clear description of the goals and objectives of a project, and produces decisions on the type, quantity, and quality of data that will be needed to meet those goals and objectives. The DQO process is a specialized type of systematic planning (USEPA, 2006).

References for QA Glossary

40 CFR 136. Title 40 Code of Federal Regulations, Part 136: Guidelines Establishing Test Procedures for the Analysis of Pollutants. Available at: https://www.ecfr.gov/cgi-bin/text-idx?SID=3cf9acace214b7af340ea8f6919a7c39&mc=true&node=pt40.25.136&rgn=div5 (accessed 26 Feb. 2020).

Ecology, 2004. Guidance for the Preparation of Quality Assurance Project Plans for Environmental Studies. Washington State Department of Ecology, Olympia, WA. Available at: https://fortress.wa.gov/ecy/publications/SummaryPages/0403030.html (accessed 6 Mar. 2020).

Gilbert, R.O., 1987. Statistical Methods for Environmental Pollution Monitoring. Van Nostrand Reinhold, New York, NY.

Kammin, W., 2010. Definition developed or extensively edited by William Kammin, 2010. Washington State Department of Ecology, Olympia, WA.

USEPA, 1992. Guidelines for exposure assessment. U.S. Environmental Protection Agency, Risk Assessment Forum, Washington, D.C. EPA/600/Z-92/001. Available at: https://www.epa.gov/sites/production/files/2014-11/documents/guidelines_exp_assessment.pdf (accessed 26 Feb. 2020).

USEPA, 2001. EPA Requirements for Quality Assurance Project Plans, EPA QA/R-5. U.S. Environmental Protection Agency, Washington, DC. EPA/240/B-01/003. Available at: https://www.epa.gov/quality/epa-qar-5-epa-requirements-quality-assurance-project-plans (accessed 26 Feb. 2020).

USEPA, 2006. Guidance on Systematic Planning Using the Data Quality Objectives Process EPA QA/G-4. U.S. Environmental Protection Agency, Washington, DC. Available at: https://www.epa.gov/sites/production/files/2015-06/documents/g4-final.pdf (accessed 26 Feb. 2020).

USEPA, 2009. Guidance for Labeling Externally Validated Laboratory Analytical Data for Superfund Use, OSWER No. 9200.1-85, EPA 540-R-08-005. U.S. Environmental Protection Agency, Washington, DC. Available at: https://www.epa.gov/nscep.

USEPA, 2014. Compendium: Project Quality Assurance and Quality Control: Chapter 1. U.S. Environmental Protection Agency, Washington, DC. SW-846 Update V. Available at: https://www.epa.gov/sites/production/files/2015-10/documents/chap1_1.pdf (accessed 26 Feb. 2020).

USEPA, 2016. Definition and Procedure for the Determination of the Method Detection Limit, Revision 2. EPA 821-R-16-006. U.S. Environmental Protection Agency, Washington, DC. Available at: https://www.epa.gov/sites/production/files/2016-12/documents/mdl-procedure_rev2_12-13-2016.pdf (accessed 6 Mar. 2020).

USEPA, 2020. Glossary: Environmental Sampling and Analytical Methods (ESAM) Program. U.S. Environmental Protection Agency, Washington, DC. Available at: https://www.epa.gov/esam/glossary (accessed 26 Feb. 2020).

USGS, 1998. Principles and Practices for Quality Assurance and Quality Control. Open-File Report 98-636. U.S. Geological Survey, Reston, VA. Available at: https://pubs.usgs.gov/of/1998/ofr98-636/ (accessed 26 Feb. 2020).

WAC 173-50-040. Title 173 Washington Administrative Code. Accreditation of Environmental Laboratories: Definitions. Available at: https://apps.leg.wa.gov/WAC/default.aspx?cite=173-50-040 (accessed 26 Feb. 2020).