August 2022 progress report to the Port of Seattle on the Urban Kelp Research Project

Seattle Aquarium | *Conservation Programs and Partnerships*

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Contents

1 Overview

This report is partitioned into two primary halves, with the addition of introductory *Overview* and a concluding *Next-steps* sections. The first primary half, *Field Work*, reports progress and lessons-learned from preliminary days in the field with Port of Seattle personnel, including site evaluations, canopy kelp-forest operations, ROV methodological experimentation, tests of the acoustic GPS, and problem-solving regarding an emergent leak within the ROV. The latter half, *Analyses* deals with progress regarding data management and analysis, including the development of a complete analytical workflow for ROV telemetry and sensor files, video processing, and preliminary image annotation in CoralNet to calculate percent-coverage of species and habitat type. Thanks to funding from the Port of Seattle, on August 16*th* Megan Williams was brought onboard as a Research Technician for this project. She is providing instrumental support with regards to data management, video processing, statistical analyses, and fieldwork. Her funding is currently through the end of this year and we are actively seeking funds to keep her on. In sum, we are in a strong position to make a push in September to complete our summer surveys while bull kelp is still present, and we will continue to develop our analyses to next include preliminary maps of our ROV surveys.

2 Field Work

2.1 *Overview of preliminary summer 2022 field days*

Thanks to vessel support from Randy Edwards and other Port of Seattle personnel, we were out on the water August 8*th*, 12*th*, and 15*th*. Our objectives were to (*1*) develop site-familiarity of locations of interest to the Port, and (*2*) evaluate how to optimally structure ROV surveys given the configuration of Elliott Bay kelp beds. We explored the riprap along the Elliott Bay Marina, the kelp forest to the west of Elliot Bay Marina, Smith Cove where rock were deployed for bull kelp restoration, and several sites along Centennial Park. By August 15*th* we had developed our survey methods sufficiently that we completed six $100m$ transects at two sites offshore of Centennial Park. You can see video previews of these surveys from both the downward-facing (see here & here) and forward-facing cameras (see here & here).

2.2 *Operating the ROV within canopy kelp forests*

One of the foremost uncertainties regarding operating a ROV within canopy kelp forests is the potential for the ROV's tether to become entangled such that the ROV becomes immobilized. We are pleased to report that due to the relatively small size of the ROV, its high maneuverability, and a positively buoyant tether, we have developed a protocol for surveying into—and then successfully extricating the ROV out of—canopy kelp forests, without incurring serious entanglement. This requires careful communication and coordination between the two ROV and tether operators. The protocol for ROV extraction from a kelp forest is as follows (and you can see video of this here.):

1. At the conclusion of, e.g., a 100m transect into a forest with thick canopy, pivot the ROV 180°, pan the built-in ROV camera upwards, partially ascend the ROV, and obtain a visual on the path of the tether back towards the vessel.

2. Carefully start to follow the tether back out of the bed. Maintain tight tether control by reeling up the slack as the ROV motors back towards the vessel.

3. The ROV operator will need to maneuver around, above, or under, e.g., bull kelp stipes or tangles of stipes and blades. Thanks to the buoyant tether, these maneuvers are best

conducted near the surface, and additional depth can be utilized when necessary (see the latter half of Fig. 1 for the depth profile while maneuvering out of a bed).

4. In instances where the tether has been obstructed (but not wrapped) by, e.g., a large mass of bull kelp fronds, careful application of tension on both ends of the tether from (*1*) the tether operator and (*2*) the ROV by targeted thrust may pull the tether free.

2.3 *Acoustic GPS system*

These preliminary days with the Port enabled testing of our WaterLinked G2 Acoustic GPS system (see here for details). This system operates with (*1*) an acoustic transmitter attached to the ROV, (*2*) an acoustic antenna deployed off of the vessel that receives communication from the acoustic transmitter, and (*3*) a topside-hub on the vessel that obtains a GPS fix, is connected to the ROV's laptop, and integrates information from the acoustic system. When all three components are in place, we can record and export precise geospatial coordinates of the ROV's position underwater (see the *lat* and *lon* columns of this cleaned ROV telemetry file).

There are seven channels corresponding to seven frequency bands for the acoustic transmitter and antenna (see here for details). We initially encountered acoustic interference along channels 1 and 3 (along the $31.25 - 62.5$ and $93.75 - 125.0$ kHz bands, respectively), and eventually found that channel 5 ($156.25 - 187.5$ kHz) consistently worked.

2.4 *ROV survey methodology development*

Having developed the methods necessary to successfully operate within canopy forests, and with reliable ROV position information, we experimented with different modalities of benthic surveys and landed upon a protocol tailored to the Port of Seattle kelp beds. The kelp beds around Elliot Bay Marina and along Centennial park are narrow (down a depth gradient, perpendicular to shore) and long (parallel to shore). We found it works well to run the ROV "down" a bed, i.e., parallel to shore and through the thick of the forest. Given the narrow nature of the beds (perpendicular to shore), we can complete transects (*1*) within the bed along the inside-margin (shallow, relatively close to shore), (*2*) down the middle of the bed, (*3*) within the bed along the outer-margin (deeper, relatively distanced from shore), and (*4*) just outside the bed. As the acoustic GPS has a $100m$ range, and as we have a $150m$ tether, we are successfully able to conduct $100m$ transects. Depending upon current and how hard the ROV motors need to work, we can complete three or four transects on a single battery of the ROV (we have three ROV batteries).

2.5 *ROV leak*

The ROV presented a leak at the end of August that necessitated rescheduling a couple days in the field with Port. Identifying the source of this leak has been a process of trial-and-error, and we have tackled multiple potential fail points: (*1*) we replaced the acrylic housing for the electronics compartment as there were small scratches running across the double O-ring seal, and (*2*) we replaced all the O-rings in the ROV. On August $7th$ we definitively identified a failed power cable as the source of a small leak, and a new cable has been ordered—as have numerous spare parts—to ensure future leaks do not delay operations. Furthermore, we are exploring the idea of purchasing a second ROV with a complete set of hardware, such that if one ROV goes down, the second can be seamlessly rotated into the field.

3 Video and data management and analyses

3.1 *Analytical workflow development*

We have developed an overarching workflow and the associated details for the precise steps and code necessary to perform a variety of functions related to file management for the ROV telemetry files and $4K$ $30fps$ video and extracted stills. All required steps are codified in our *Overarching_Workflow* document (linked here; click either the “view raw” or “download” button), as is a tracklog to monitor file status. This document also lays out file naming conventions, file paths, links to requisite open-source code, etc. The steps are grouped as follows:

A: Configure a local machine to access open-source CCR files, conduct analyses, and push edits to GitHub repository.

B: Extract, save, and backup ROV telemetry (.csv) and Ping Sonar Alitimeter (.bin) files and benthic- and forward-facing GoPro video (.mp4).

C: Work with and merge the .csv and .bin files to generate a dive log at the $1s$ scale, i.e. with one second intervals (rows), including latitude and longitude, distance traveled between coordinates, ROV altitude above the seafloor, depth, temperature, etc.

D: Video processing such as clipping the .mp4 videos to the precise survey transects, color-matching (if needed), and extracting and saving stills from video.

E: File management to save and back-up cleaned/processed video and stills and eventually delete older file versions.

F: Upload image stills to CoralNet, annotate imagery with percent-cover categories, review and correct (if necessary) algorithm predictions, save and download the .csv CoralNet file.

G: Merge the CoralNet .csv containing species and habitat data with the merged ROV telemetry .csv file to produce a final combined ROV telemetry plus community and habitat data.

3.2 *Mapping Station at the Seattle Aquarium*

We are working with the Seattle Aquarium’s IT department to develop a custom *Mapping Station* at the Market Square building. This will include a computer optimized for processing speed, memory, and intensive video/analytical tasks such as the compilation of Artificial Intelligence (AI) algorithms and processing of $4K$ imagery on $4K$ computer screens.

This *Mapping Station* will provide an onsite base for our project, and in addition to using it ourselves, we envision it will provide an interface for volunteers and also Port of Seattle personnel or associates that want to become familiar with video processing, AI analyses, mapping, etc. We look forward to opportunities to share our code, video processing approach, AI methods, and spatial analyses in-person with interested parties.

3.3 *Open-source resource development*

We are striving to maintain transparency and accessibility throughout this project, both with regards to hardware such as our customized ROV, as well as software, including maintaining a record of code, changes made to code, and the use of open-source programs where possible. We currently have two public repositories on GitHub:

- Seattle_Aquarium_ROV_development contains general information that may be of interest to collaborators or members of the public. It provides a broad overview of our project including links to summary documents, articles and interviews, information about the ROV and links to its components, and links to photos and video from the ROV.
- Seattle_Aquarium_ROV_telemetry_imagery_analysis is more in the weeds, and contains code to convert and manage files, extract stills from video, create figures, as well as links to coding and analytical resources. As it is public, interested parties can clone (i.e., download) this repository to their local machine in order to conduct the same analyses, file conversions, and data management, assuming they have the required programs (linked here) installed.

3.4 *Video processing*

The only program we are currently using that is not freely open-source is Cyberlink PowerDirector, a subscription based video editing program. With this program we can trim files down to specific survey transects, as well as color match to correct any instances in which the white balance deviates.

Furthermore, we now have Python code in place to extract stills from the $4K$ $30fps$ GoPro video. As we can easily control the interval at which stills are extracted (e.g., take a still every 5, 10, or 20 seconds), we can ensure that for any given ROV dive, our stills do not overlap one another (i.e., double-count), nor do they miss information in-between stills (i.e., under-count).

3.5 *Telemetry files*

We have developed the steps and code to work with and manage (*1*) the .csv telemetry file containing a record of the ROV's dive, including latitude/longitude information, and the (*2*) Ping Sonar Altimeter .bin file, containing a record of the ROV's height above the seafloor. The telemetry file required extensive pruning, code for which you can find here. The .bin Ping file required conversion from .bin to .csv (code here). The Ping data required a bit of massaging (e.g., here) as it samples many times per second and we needed to merge it with the ROV telemetry file which is at the $1s$ scale. You can see code for merging these files here.

(a)

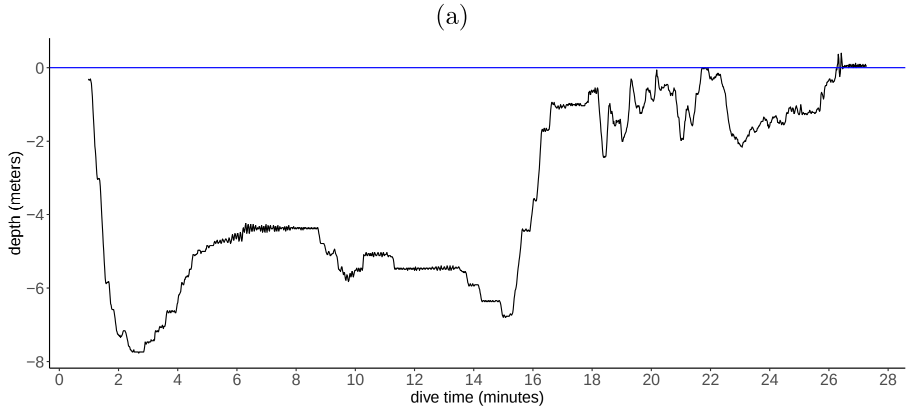

Figure 1: (a) the depth log of one of the August $15th$ surveys, with the first half recording a profile of a survey, and the latter half recording depth while navigating out of a kelp bed.

You can see an example of a completely cleaned and processed ROV telemetry file here with columns such as time in $hh : mm : ss$ (*time*), a running tally of the ROV's flight time (*flight_time*), depth, compass heading (*heading*), *battery_remaining*, and geospatial information such as latitude

(lat), longitude (lon), and the distance in meters between each GPS point ($EucDIS$). The last two columns contain information from the Ping Sonar Altimeter such as the ROV's distance above the seafloor (avg_dist) and percent-confidence (avg_conf).

3.6 *Preliminary CoralNet analyses*

We used the open-source AI web interface CoralNet to create a project, upload percent-cover categories, and annotate a preliminary set of images (Fig. 2). You can review the list of percent-coverage categories for species as well as habitat type here (click either the "view raw" or "download" button). Once these categories were entered into CoralNet, we uploaded extracted stills from our $4K$ video from offshore of Centennial Park, and conducted a preliminary proof-of-concept series of annotations. Once the annotations were complete, we exported the resulting .csv files, and merged them with the relevant rows from the ROV telemetry file. What you see here (click either the "view raw" or "download" button) is the final product of our analytical workflow chain of events, i.e., the complete record of our dive including depth, latitude/longitude, Ping Altimeter data, as well as the corresponding community structure identified at those precise seconds throughout the dive.

(a) (b)

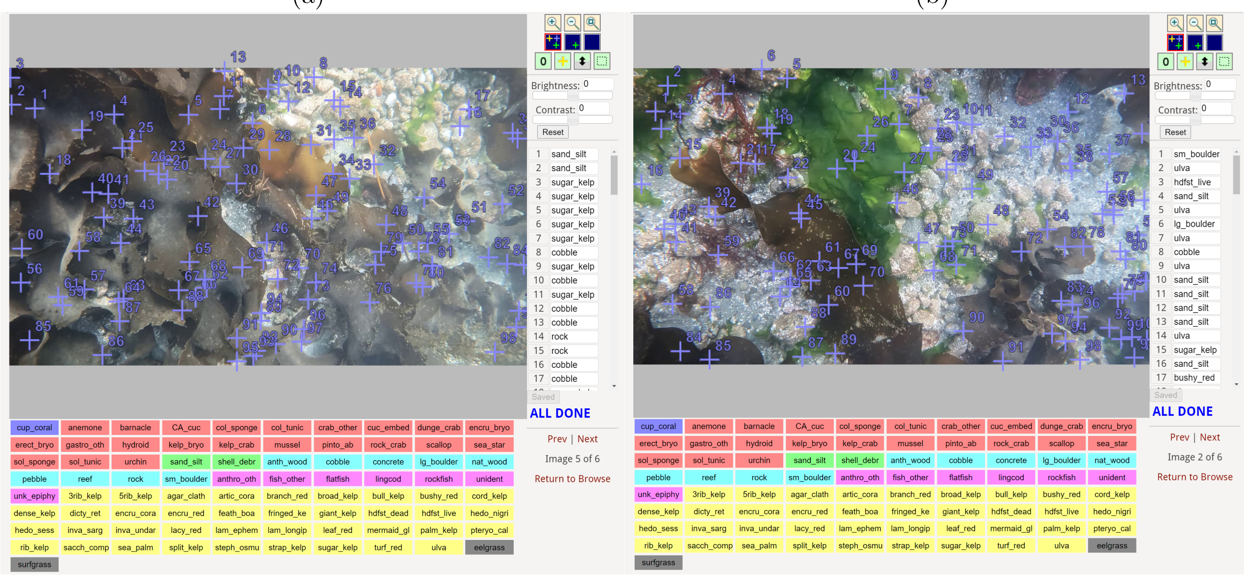

Figure 2: (a) & (b) two different stills extracted from $4K$ $30fps$ GoPro video uploaded and annotated within Coral to calculate percent coverage of various species as well as substrate type.

4 Next-steps

Our next-steps in the field include a flurry of surveys in September to finish our summer 2022 work in Elliot Bay, along Centennial Park, and in the East and West Waterways. On the analytical side, having developed our analytical workflow, we will enact it through processing full-length ROV dives, as well as initiate community/habitat data visualization. We will also simultaneously push to develop the mapping portion of this project through using the latitude/longitude coordinates recorded by our GPS system. In short, we are on track and we look forward to advancing this project with Port personnel.