BENTHIC COMMUNITIES IN PORTIONS OF COOS BAY, OREGON SLATED FOR SHIPPING CHANNEL EXPANSION AND MITIGATION

by

MATTHEW N. DEPAOLIS

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Student: Matthew N. DePaolis

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This thesis has been accepted and approved in partial fulfillment of the requirements for the Master of Science degree in the Department of Biology by:

Dr. Craig Young	Chair
Dr. Janet Hodder	Member
Dr. Alan Shanks	Member

and

Andy Karduna	Interim Vice Provost for Graduate Studies

Original approval signatures are on file with the University of Oregon Division of Graduate Studies.

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THESIS ABSTRACT

Matthew N. DePaolis

Master of Science

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Title: Benthic Communities in Portions of Coos Bay, Oregon Slated for Shipping Channel Expansion and Mitigation

Benthic communities at four proposed dredge areas within the main navigation channel of the Coos Bay estuary were sampled in November 2020 and February 2021. Trawls and grabs were used to survey benthic and infaunal organisms, respectively. Neither distance from the estuary mouth nor depth were significant variables in predicting the presence of any species surveyed. There was a significant correlation in the November trawls between the presence of the flatfish *Pleuronectes vetulus* and the shrimp *Lissocrangon stylirostris*. Dungeness crab, *Metacarcinus magister*, *P. vetulus* and *L. stylirostris* presence were similarly significantly correlated during the February trawls. Shoot density, blade area, and epibiont communities were compared between two eelgrass beds slated for dredging and transplantation. Sites were statistically different in both shoot density and blade area. The sites also exhibited different epibiont communities, one being dominated by Arthropoda and the mitigation site occupied mainly by gastropod molluscs and their egg masses.

CURRICULUM VITA

NAME OF AUTHOR: Matthew N. DePaolis

GRADUATE AND UNDERGRADUATE SCHOOLS ATTENDED:

University of Oregon, Eugene
University of Wisconsin, Madison

DEGREES AWARDED:

Master of Science, 2021, University of Oregon
Juris Doctorate, 2021, University of Oregon
Bachelor of Arts, 2012, University of Wisconsin, Madison

AREAS OF SPECIAL INTEREST:

Marine Biology
Ocean and Coastal Law

PROFESSIONAL EXPERIENCE

Lab Intern, Mote Marine Lab
Sarasota, FL 2/15 to 6/15

Field Research Assistant, Shedd Aquarium
Chicago, IL 12/12 to 6/13

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CHAPTER I: INTRODUCTION

Background Information

The protection of natural waterways for public use is one of the earliest concepts in an English-based system of laws. The idea that shore areas, running water and navigation channels are protected for use by the general public is enshrined in our legal system based on similar ideals stemming from early Roman and English law systems (Sax 1970). While the exact nature of the public trust doctrine has evolved throughout the years, it has remained a cornerstone protection for the waters of the United States, protecting the freedom of navigation and fishing for the public (Huffman 2007). Since their conception, the protections of navigable waters for the general public have been balanced with the needs of private enterprise (Sax 1988). Whether regulating the redirection of water flow to power mills, or the use of streams to move vast quantities -of logs, the public trust doctrine has never excluded uses of waterways by industry that do not overly burden the public. Today, a series of laws has been enacted by Congress to allow for development to continue without causing undue harm to the general public. Legislation such as the National Environmental Protection Act (NEPA) ensure that major federal actions do not impact the environment in unexpected ways (*National Environmental Policy Act of 1969* 1970). NEPA requires that federal permits only be granted after a 'hard look' is taken at any potential impacts from the proposed action. In order to meet this standard, a reasonable interpretation of the available science is necessary. Gaps in science can leave individuals granting permits in a position where their decisions do not fully consider all potential ramifications to an environment. Instead dissimilar studies may end up being used as justification for a federal action without adequate consideration for the true state of the environment in question. Despite the complex series of established laws, the governing body's goals may be subverted by deficient or incomplete science.

Our government is founded on the basis of a system of checks and balances. The Constitution establishes the executive, legislative and judicial branches of government, all with distinct roles in the government. The Legislative branch has been charged with crafting laws, and the Executive is in charge of enacting them. From this relatively simple idea, a sprawling bureaucracy has expanded as our government has grown and become more complex. Most actions undertaken today by the federal government take place not in the halls of congress, but instead in one of the many agencies within the administrative state. Everything from nutrition standards to aquatic pollutant limits are set within agencies of the executive branch. Because the responsibilities of many government decisions fall upon unelected administrative representatives, it is imperative that the complex labyrinth of bureaucracy be well understood and followed by both the agencies and the parties who rely on decisionmakers within the executive agencies.

The basis for the supervision of the decision and rulemaking ability of the executive branch is the Administrative Procedures Act (APA). The APA was passed by Congress to streamline the legislative process and ensure that executive agencies were all operating in a similar manner with similar oversight. With the passing of the APA, the modern administrative state as we know it was formed. The executive agencies take the intent of the broad legislation passed by Congress and enact specific rules. The APA dictated that the agencies must use one of two standardized rulemaking procedures, formal or informal. Formal rulemaking closely resembles court proceedings and generally occurs when statutorily required. Informal rulemaking imposes requirements that the public have notice of the proposed rule and are afforded an opportunity to provide comments. This ensures that agency actions are not taken without the public's knowledge. While some of these 'rules' are the passing of new agency standards or controls, they also can be decisions concerning the allocation of public resources such as the permitting of federal actions, including the signing of leases on federal land. In order for the Jordan Cove Energy Project (JCEP) to receive the permits necessary for their project they must undertake informal rulemaking procedures for multiple government agencies. Depending on the permit sought, the JCEP must follow the procedures to the standards established by each act and agency. In order to secure a permit for the dredging of the Coos Bay estuary, for example, the JCEP must adhere to the requirements established in the Clean Water Act (CWA), as well as state and local waterway and land use permits.

The CWA was established in order to ensure the protection of ‘Waters of the United States’. The federal government asserts jurisdiction over those waters within the United States that are considered to be ‘navigable’. Navigable waters are those that are connected to, or able to be used for transport or trade. Therefore, most streams, rivers, and bodies of water are under the purview of the federal government. Regardless of current debates that are too complex to detail here about the precise nature of navigable waters, the coastal waterways and ports of the United States all are under the jurisdiction of the United States Federal Government. The CWA aims to protect these waters from undue pollution, obstruction that would impair their use by the public, or anything that would prevent them from being used for their stated aims. Different designations of waterways are afforded different protections based on their health, status, and uses. A common protection within the CWA is the anti-degradation policy, which prevents anyone from degrading the overall quality of that waterway to the point that it cannot be utilized for its codified purpose. Much of the CWA deals with pollutant discharge and other protections. However, one of the commonly utilized sections of the CWA concerns dredge and fill permits. §404(d) of the CWA establishes the requirements of permits for any dredging or filling actions within waters of the United States. The Army Corps of Engineers has been charged with approving or denying these permits. While they are given large latitude to grant permits, due to the nature of the projects they are usually required to adhere to other legislation as well, most notably the National Environmental Protection Act or NEPA.

NEPA was enacted by Congress in 1970 in order to ensure a better understanding of the ramifications of actions taken by the federal government. While NEPA doesn’t require any specific action by decisionmakers to be taken, it forces actors to ensure, to the best of their ability, any potential ramifications from the action they are proposing to take are understood. NEPA procedures are enacted for any major federal actions that affect the environment. NEPA procedures require the environmental impact to be surveyed and published publicly to allow for citizens to weigh in and comment on the proposed action, per the informal rulemaking requirements of the APA. Major federal actions are generally anything done by the Federal Government that is more impactful than a small administrative change within the agency. 'Actions' are considered to occur not only when undertaken on behalf of the government, but also when private persons wish to take an action that requires a federal permit. The 'environment' within this phrase is not limited to the natural environment, but also includes the human environment. This encapsulates aesthetic, community, and historical value of an area beyond simply the nature that exists at a site. In order to fully understand the potential ramifications of an action, Environmental Impact Statements (EIS) are required for federal actions. There is an opportunity to undertake a less rigorous Environmental Assessment (EA), if the action is likely to not have an outsized effect on the environment. EAs have a condensed timeline and lessened requirements and are generally more desirable than an EIS for persons wishing to streamline their project. However, they also carry some inherent risk. If an organization completes an EA and it is found that the environment is likely to be affected, it will be necessary to restart the process and complete the full EIS, further slowing down project. Once an EA or EIS is complete, they are posted in the federal register and submitted to the general public for comment. Individuals and organizations are then free to comment for a set amount of time. The permit applicant is then allowed to respond to the comments and the agency in charge of the permit will then issue a final Record of Decision (ROD) on whether or not the permit will be granted. It is a requirement of NEPA that a 'hard look' be taken at the available science.

The JCEP has applied to build a Liquified Natural Gas (LNG) terminal on the northern edge of the main channel of Coos Bay. The terminal will intake natural gas from the Pacific Connector Gas Pipeline across southern Oregon. There it will supercool the gas, condensing it to a liquid state. Once liquified the LNG will be loaded onto large tankers which will then make their way across the Pacific to Asian markets (FERC 2019). In order to allow these supertankers to pass through the bay, it is proposed that excavation dredging will be used at four sites between the mouth of the bay and the location of the planned facility, to widen and deepen the channel to a depth of 40ft.

Table 1. Locations of proposed dredge sites for the Jordan Cove Energy Project.

Site	Length (m)	Southmost Point	Northmost Point	Heading
1	1284	43°21’16.74”N, 124°19’13.55”W	43°21’53.82”N, 12418’45.85”W	28.30°
2	1078	43°22’42.22”N, 124°17’42.95”W	43°23’11.04”N, 124°17’15.84”W	34.18°
3	393	43°24’10.99”N, 124°16’42.07”W	43°24’10.99”N, 124°16’42.07”W	16.13°
4	550	43°24’49.00”N, 124°16’28.42”W	43°25’05.29”N, 124°16’17.86”W	24.72°

Two of these areas lie on the western side of the main shipping channel within the estuary while the other two lie to the east (Figure 1). Maintenance dredging occurs in Coos Bay roughly every 10 years, but excavation dredging will be necessary to allow for the massive LNG tankers to enter (FERC 2019). The planned site for the JCEP LNG condensation plant is on the northern edge, about midway through the estuary

In order to allow for the passage of increasingly larger transport ships our ports and navigations channels must be shaped through the dual processes of construction and maintenance dredging. Construction dredging is utilized to craft new navigational accommodations for ports and waterways using underwater excavation. Maintenance dredging is the “removal of materials as necessary to keep water ways at the originally constructed depths and widths” (National Research Council, Marine Board 1985). Dredging in practice is the process of removing sediment or bedrock from an underwater area, using suction pumps, buckets or auger systems. During suction dredging, sediment is removed either by using high velocity water to blast the sediment out of an area or by using suction to remove the undesired sediment and transport it elsewhere (Newell 1998). Suction dredging results in large amounts of material, or 'spoilage' that must be transported and deposited to an alternative location, either terrestrial or marine. Spoilage can have an acute deleterious effect on the areas where it is deposited. Spoilage can be detrimental whether redeposited back into marine environments or deposited on land, both in the resulting burial of organisms, and depending on potential pollutants found within the sediment. While dredging and spoilage are inextricably linked, my survey of marine communities focuses solely on the areas of planned dredging for the JCEP and the benthic communities that reside in those areas.

The dredging is slated to take place within an October to February 'in-water work window', required by the Oregon Department of Fish and Wildlife. This time was chosen in order to minimize risk of potential 'takes' of Coho salmon (FERC 2019). The Oregon Coast population of Coho salmon is listed as threatened under the Endangered Species Act (ESA), resulting in extra protections than a non-listed species. If an action has a chance of harassing, harming, or killing an animal protected under the ESA additional permits are necessary (*Endangered Species Act of 1973* 1973).

The Coos Bay estuary has an area of 54 km^2. It is relatively shallow with approximately 50% of the estuary made up of intertidal flats (Eidam et al. 2020). The benthos of the estuary's main channel inhabits an area comprised of fine sand covered with shell hash nearer to the mouth of the bay. The estuary is formed by the Coos River draining into the Pacific Ocean through a large S-shaped bend curving towards a narrow inlet on its southern edge (Figure 1).

The Coos Bay estuary provides important habitat for the spawning, rearing, and growth of many organisms, some of which are harvested by humans. Dungeness crabs spawn within the estuary before their larvae are flushed out to sea within the plankton (Rasmuson 2013). Chinook and Coho salmon use the bay at different stages of their lives (Magnusson and Hilborn 2003). Transient species feed on benthic organisms that make their home in the sediment of the estuary and on the shell hash that litters the bay. Beds of eelgrass, *Zostera marina*, form nursery areas and hunting ground for juvenile species, and habitat for their prey. While smaller beds are found around the edges of the bay, a large 19-acre eelgrass meadow is found on the eastern side of the main channel, south of the airport (FERC 2019). Recreational fishermen capitalize on the varied habitats within Coos Bay, harvesting amongst others, crab, clams, sand shrimp, salmon, rockfish, and ling cod. The proposed dredging action for the JCEP would disturb these habitats present within the main channel and could impact the complex food webs present. As species are affected within the estuary, the worry of a cascade of effects through the trophic levels becomes more acute.

The proposed dredging action is more disruptive than the current maintenance dredging that occurs in Coos Bay because it impacts areas that have not been previously disturbed by this activity. Due to the nature of the proposed widening of the channel, permitting for the JCEP is considered a "major federal action" and is required to follow the procedures established under NEPA, including a full EIS. In order for a proper EIS to be completed and decisionmakers be adequately informed, it is imperative that robust scientific studies are available.

Currently, the project has had permitting issues at both the state and federal levels. While there are myriad claims being brought against this project, from attempting to block federal land seizure to climate change litigation, this study aims to strengthen the current knowledge of the benthic community highlighted within the JCEP dredging application. Within the original EIS for the project there was a lack of any meaningful evaluation of the benthic and eelgrass communities that would be disturbed by the dredging action. Due to the complex nature of the varied habitats present within the project area, it is imperative that robust surveys are carried out to better inform decisionmakers of the potential ramifications of their permit decision. These surveys are necessary because the current body of work being relied upon allowed them to draw the conclusion that a four-week recovery to pre-dredge conditions was likely after completion (FERC 2019). However, the study that was relied upon for this conclusion was based on a different type of habitat than the habitat present in the main channel of the estuary.

Estuarine Benthos

The original claims contained within the EIS relied upon a review of past dredging activities, summarized recovery times after dredging occurred, and factors that influenced the rate of recovery (Newell 1998). Newell 1998 claimed that Coos Bay is able to recover from dredging in a matter of weeks. The basis for the recovery time claim is a single row of a table, cited to a study by McCauley (McCauley et al. 1976). The Newell 1998 figure states that Coos Bay is an estuary with a sediment type of "disturbed muds" and "recovers from dredging in 4 weeks." McCauley based his conclusions based on a small survey in a slough far from the main channel. Despite McCauley observing a rapid recovery times at a few of his sample sites, he was the first to admit that the "readjustment rates" his study focused on "does not connotatively predict the long-term outcome" (McCauley et al. 1976). McCauley carried out a small survey of an area that was scheduled for maintenance dredging. In the paper, McCauley took six grab samples at six sites from the mouth of the Isthmus Slough, a small offshoot of the main estuary fed by the Coos River and catalogued the organisms. Two of the sample sites were within the planned path of the dredge, and the other four remained outside. Many of the organisms found were small, rapidly reproducing species, such as polychaetes and oligochaetes. After samples were taken, the planned maintenance dredging was carried out in the mouth of the slough. Once the dredging occurred the area was resurveyed with grab samples. While he found that, on average, the sites returned to similar conditions within four weeks, some samples did not, and some saw no change in organisms immediately after the dredging occurred. Overall the samples were too small to make any claims about statistical differences between the area that had been dredged and the areas that had not. Due to the small sample size the McCauley study should not be relied upon to predict recovery outcomes for the JCEP associated dredging. Although the EIS bases its recovery time conclusions on the table within Newell (1998), it is within the McCauley (1976) study that the data originated.

In addition to the facial deficiencies in the McCauley study for the basis of large-scale dredging actions, and the conditions between the McCauley sites and the planned dredge area are vastly different. The area surveyed in the McCauley paper is in the mouth of the Isthmus Slough. While it is connected to the Coos Bay estuary, it is nowhere near the planned dredge sites for the JCEP and exhibits different habitat, bottom composition and ecosystem community. Newell (1998) goes into great detail about factors that influence recovery times. Two of the most important are the reproductive rates of species found within the dredging area, and the particle size and sediment type of the material being dredged. The McCauley study focused on an area of the bay made up mostly of disturbed muds inhabited by small benthic invertebrates. The main channel of the estuary has a fine sand bottom, and a more diverse benthic community, (Baker 1978). Using the criteria set forth by Newell (1998), the main channel would be predicted to have a different recovery time than the time proposed by McCauley and relied upon in the original EIS. Therefore, to provide an adequate understanding of the impacts of the JCEP proposed dredging action it is imperative that the area is properly surveyed.

Part of the planned dredging action involves construction dredging an access channel on the northern end of the estuary (Figure 16). This would necessitate an access channel to be cut allowing tankers to traverse from the main channel of the estuary to a slip that would be built at the LNG terminal. In order for this access terminal to be built, it would be necessary to dredge through an eelgrass bed that is currently situated in front of the Jordan Cove property.

Eelgrass

While eelgrass, *Zostera marina*, is an angiosperm and produces seeds, it primarily spreads vegetatively resulting in rhizome mats upwards of 10m thick. The eelgrass shoots form dense meadows that serve to remove carbon dioxide from the water, output oxygen and, by slowing the water current, capture sediment which provides a substratum for infaunal organisms (Duarte 1999). The blades of eelgrass are often covered with algal and invertebrate epiphytes (Borowitzka et al. 2007). Eelgrass is an important foraging habitat and refuge for small fish, is a food for waterfowl, and an important substrate for herring spawn (Bertelli and Unsworth 2014).

Due to the importance of eelgrass as a habitat, it was designated as Essential Fish Habitat (EFH) during the 1996 reauthorization of the Magnuson-Stevens Fishery Act (*Magnuson-Steven Fishery Conservation and Management Act* 1976). Under this EFH designation, actions that would cause harm to eelgrass must include a consultation with NOAA in order to minimize any negative effects. The Department of State Lands within Oregon also requires eelgrass mitigation to occur. JCEP has sought to reduce potential harms to eelgrass from dredging by transplanting eelgrass to a new bed that they have deemed the "mitigation zone" (FERC 2019). The mitigation zone is planned for an area south of the airport, adjacent to an existing19-acre eelgrass meadow (Figure 16). This patch is slated to serve as a 'donor patch' for the mitigation zone. The planned mitigation area has patchy eelgrass cover in an intertidal mudflat. The current plan for the mitigation zone involves transplanting as much of the two acres of eelgrass taken from the proposed LNG terminal access dredge area as possible. Further transplantations would be taken as needed from the healthy 'donor patch', until a total of 3 acres has been transplanted. An additional 7 acres of 'suitable area' for eelgrass habitat will be prepared at the same time, with the hopes that it will eventually be colonized naturally (FERC 2019). JC will then monitor the site for five years to ensure that the program was a success. However, it has been demonstrated that eelgrass transplantations may take up to 30 years to determine if they have been successful or not (Tomasko et al. 2018). While the dredge area and mitigation zone are both eelgrass beds within the main channel of the estuary, they have different conditions. If the transplantation is successful, that is no guarantee that the new habitat will provide a comparable replacement to the lost eelgrass beds. In order to understand if the habitat and communities at the two sites are similar, it is necessary to survey both sites. By evaluating the two sites by shoot density, relative blade area, and communities of epibiota I was able to provide a better understanding of the similarities between the two sites.

The dredging application this survey relates to is only one small piece of the JCEP. As with many large-scale building projects, it is necessary for JCEP to obtain many permits at the federal, state, county, and city level for permission to carry out their project. For the dredging alone, the JCEP requires federal permits for the Clean Water Act, the Coastal Zone Management Act, a state permit from the Department of state lands for fill and removal, and three county, as well as one city permit for four different Navigation Reliability Improvements. Although the proposed dredging action is a small part of the whole project, it is imperative that robust science be utilized during the decision-making process. In order for decisionmakers to understand what impacts the additional dredging will have on the benthic communities within Coos Bay it is necessary to undertake additional surveys. Sampling the benthic environment and sediment of the proposed dredge area using trawls and grab samples will provide a better understanding of what the benthic community composition, and possibly provide stronger insights into what a recovery time would look like. Combining these samples with surveys of the eelgrass beds within the channel access zone and the mitigation zone, I hope my project will provide a more comprehensive picture of the organisms that make their home within the navigation channel of Coos Bay.

CHAPTER II: Bottom fauna of the proposed dredge sites for the Jordan Cove Energy Project

The planned dredge activity associated with the JCEP (Jordan Cove Energy Project) will remove sediment from four separate areas within the main channel of the Coos Bay Estuary. Described as navigation adjustments, all four sites occur between the mouth of the estuary and the planned docking site for the JCEP. The proposed dredging would make changes to the navigation channel, expanding the length of the channel by between 225ft and 2,500ft, depending on the site. The dredging activity would also widen the channel by roughly 100ft at most sites except in the case of site 2 where it will be increased by 1,150ft. A total of 590,000cy of material will be dredged (FERC 2019). All of this dredging work is slated to occur within the planned work widow from October to February.

To assess the likely impact of the proposed dredging on the bottom fauna, I sampled the dredge sites using benthic grabs and trawls. Grab samples were collected to characterize and enumerate the infaunal species within the channel. Trawls were used to characterize the composition and distribution of the benthic epifauna that were likely to be directly disturbed by a dredge. Within Coos bay these communities are mostly invertebrates and fish, some of which are commercially important. In addition to the species captured in the trawls, large amounts of shell hash were also recovered. The epibiota of the shell hash was catalogued to form a more complete understanding of the organisms that inhabit the dredge area. Shell hash provides a habitat for animals that cannot live on soft sediment, increasing the biodiversity of the habitat. By compiling these data, a complete picture of the channel community was construed, providing a more robust understanding of the impact the proposed dredging actions would have within the estuary.

Methods and Materials

Coordinates of each site were determined using maps provided by the Jordan Cove Company overlaid on area maps using Google Earth software. The coordinates at the boundaries of each site where the planned dredge would take place were then visually determined and the approximate length of the dredge area was calculated using Google Earth.

Table 2. Distance from estuary mouth to survey areas. Distance is measured from the estuary mouth to the center point of the dredge area.

Dredge Site	Distance from Estuarine Mouth (km)
1	2
2	5
3	7.5
4	8.8

Sites were differentiated by distance from the mouth of the estuary (Table 2). Sites were sampled in November 2020 and February 2021, spanning the planned in-water work window. Samples were collected from the bottom of the channel, and the shallower side of the wall. The wall samples in the November set ranged from 5-10m and the deep samples ranged from 6-13m. The wall samples in February ranged from 6-11m and the deep samples all occurred at 12m. Sites were generally completed in sequential order, either from Area 1-4 or 4-1, when possible. Sampling was done during Dungeness crab fishing season and trawls occasionally had to be maneuvered around crab pots. Each series of sites was sampled on the same day between 10:30 and 14:30. The sampling days had similar tide profiles, with Low Tide being close to the start time, 9:42 in November and 11:35 in February. All sampling was done on incoming tides. Both sampling days finished before high tide, 15:26 in November and 17:44 in February. The November low tide was 1.2 m while the February low was 0.4 m.

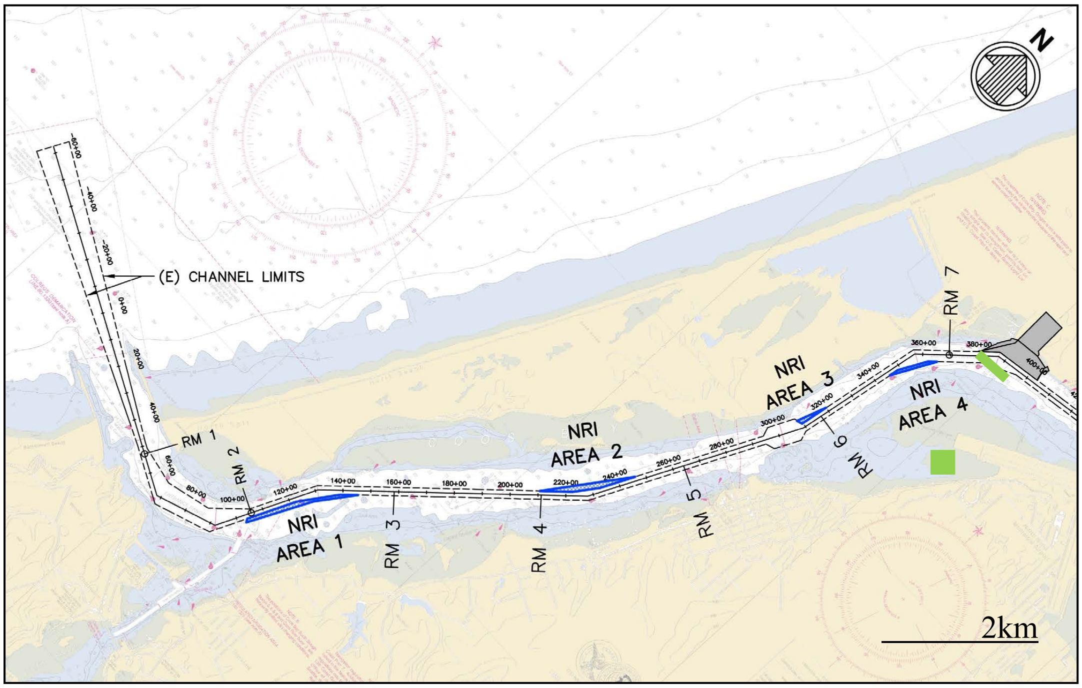

Figure 1: Navigational chart of coos bay, showing the proposed dredge areas within the main channel of Coos Bay (dark blue polygons). Areas 1 and 4 are on the eastern side of the existing channel while Areas 2 and 3 are on the western edge. The gray box on the right edge of the figure represents the planned area of the JC LNG condensation plant. Green squares signify relevant eelgrass beds. The northern-most eelgrass bed is in the proposed access channel and would be removed by dredging while the southern represents the mitigation zone.

Grab Samples

A 15x15cm Ponar grab was used to sample the organisms living within the sediment at each proposed dredge site. The grab collection device was prepped upon arrival at each site by opening the grab and inserting a spring-loaded pin into the arms of the grab device. The grab sample collection device closes when its mouth lands on a flat surface, releasing pressure on the pin holding the jaws open. Once the grab sample is pulled upward, the edges of the mouth close, digging into the sediment beneath it and collecting a sample. Due to its design, it only functioned successfully on flat sediment and therefore was not effective at collecting samples along the wall of the channel. As a result, samples were only taken from the same depth as the deep trawl at the bottom of the channel. Once the ship was positioned over bottom of the channel, the grab was released and lowered by its own weight into the water. All grab samples were taken during the February sampling session upon arrival at each site, prior to the trawl being deployed.

After being pulled on deck of the ship, the contents of the grab were transferred to containers for later processing. Once returned to the lab the samples were sieved through screens of 3.35mm, 850um, and 250um and observed under a dissecting microscope so that individual organisms could identified. Organisms were identified to the lowest possible taxonomic level.

Trawl Samples

Trawl samples were collected with a small otter trawl with a width of 3m and a 2cm mesh size. Trawls were undertaken at each of the planned dredge areas, Areas 1, 2, 3, and 4. (Figure 1). Using the coordinates in Table 1 as the boundaries, sampling trawls were undertaken from the R/V Pluteus. Once the boat reached the desired GPS location within the site coordinates the bottom or wall of the channel was located with the depth finder. Trawls were conducted on both the wall and bottom of the channel of each site. The wall of the channel was determined to be between the channel base and the natural seabed and was found by noting the rapid depth change. Two trawls were conducted at each site. Trawls were conducted parallel to the channel so that they could sample a consistent depth and a greater area of the planned dredge area. One was considered the "deep" sample and was pulled along the bottom of the channel. The other was considered the "shallow" sample and was positioned on the channel wall. The boat was then slowed to approximately 1.0 knots, the desired trawling speed. The trawl was then lowered into the water using the a-frame and hydraulic winch. Once the trawl was visually confirmed to be open in the water it was lowered until it was on the bottom. This was assessed with tactile confirmation by holding the steel cable and feeling the trawl bounce along the bottom. The trawl was then towed behind the boat for a ten minute “soak time” before being brought back onto the deck. The specific amount of distance is difficult to monitor based on drift, wind, and current, so a consistent trawling speed and soak time was used to ensure similar amounts of bottom were sampled across sites. The contents of the trawl were deposited on the deck of the boat and individuals were identified to the lowest taxonomic level. Unknown organisms were photographed for later identification. Once catalogued the organisms were returned to the water. Once a trawl was completed at a site and the organisms had been enumerated and returned to the water, the boat was repositioned either deeper or shallower depending on the previous sample that had been taken. The process was then repeated before moving on to the next site.

Many trawl samples contained shell hash in addition to the larger free-living organisms. This shell hash was collected to be processed upon returning to shore. The November samples were dried before processing. The February samples were processed wet, shortly after they were collected. Once transported to the lab, the length and width of each individual shell was measured. Barnacles were the dominate organisms on the shell hash and they were counted, and approximate percent of the shell covered by barnacles was estimated. Any additional epibiotic organisms from the February samples were also counted and identified to the lowest possible taxonomic level. Due to the drying that occurred, only barnacles were inventoried from the November samples.

Results

Grab samples

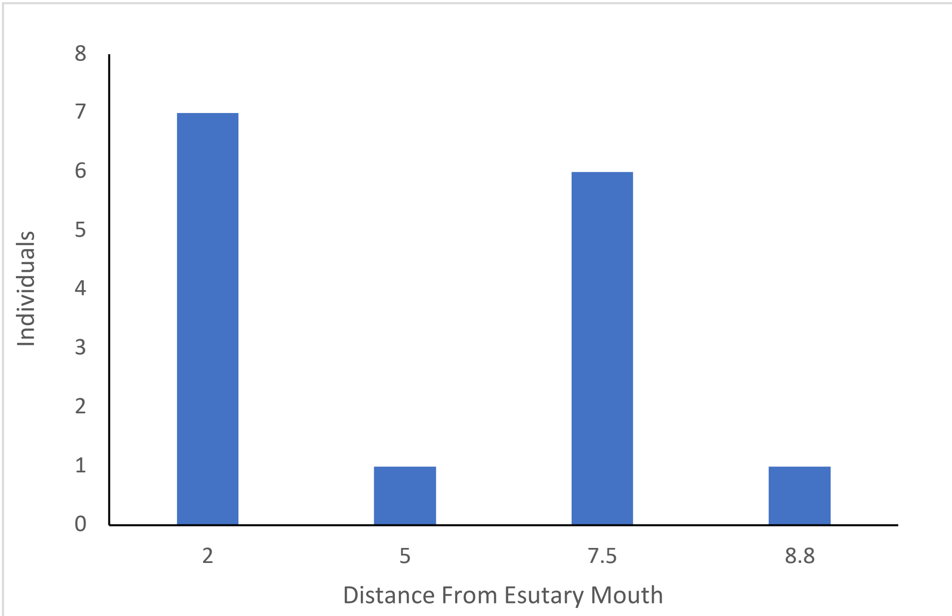

Figure 2: Number of individuals found within the grab samples at each site.

The grab sample that had the most organisms (7) was nearest the mouth of the estuary, Area 1 (Figure 2). It was also the site that had the most varied taxonomy of any of the samples. Four oligochaetes, one polychaete annelid, one sea urchin, *Strongylocentrotus purpuratus.*, and one cockle, *Clinocardium sp.* were found at site 1. The Area 2 sample yielded only one individual, an oligochaete. Area 3 yielded two polychaetes, three oligochaetes, and a single *Lissocrangon stylirostris*. Area four, the farthest from the mouth of the estuary had one organism, *L. stylirostris*.

Shell Hash

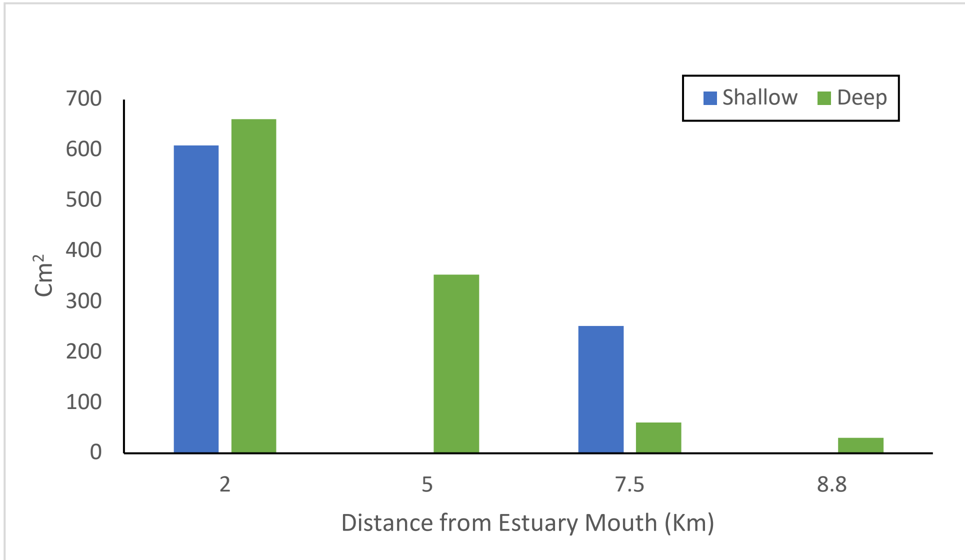

Figure 3: Total surface area of shell hash recovered in November trawls.

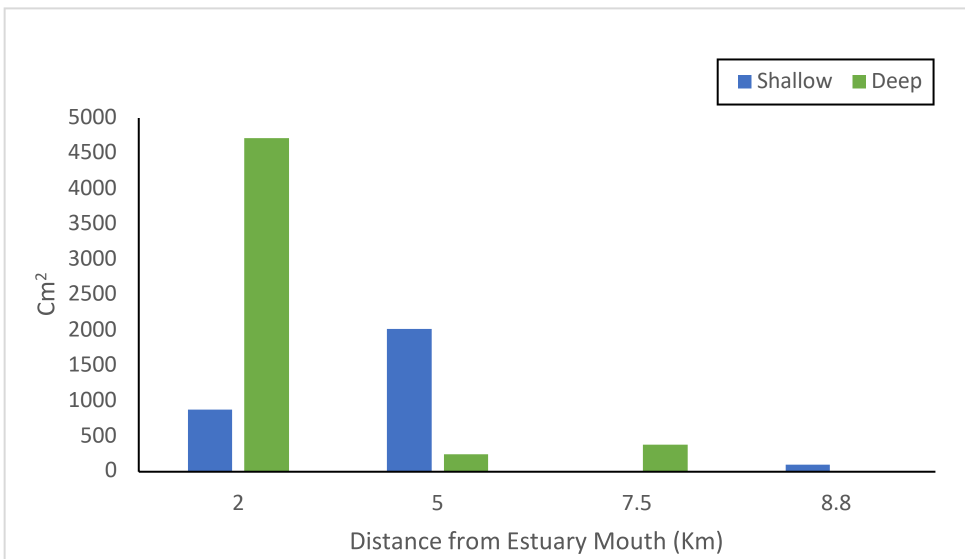

Figure 4: Total surface area of shell hash recovered in February trawls.

Shell hash was recovered at all sites. In the November trawls 31 pieces of shell hash were caught in the trawls. In the February trawl a total of 95 pieces of shell hash were recovered. Many of the shell hash pieces were covered in barnacles as well as other organisms. The total area of shell hash from the November trawl was approximately 0.4m^2 (Figure 3). There were 5066 barnacles on the collected shell hash with an average of 163±273 barnacles per shell (Figure 5). On average 14±22% of the shell hash surface being covered by barnacles (Figure 7). The February trawl yielded approximately four times as much shell hash as the November trawl. In total 1.67m^2 of shell hash surface area was recovered (Figure 4). Covering this shell hash were 11166 barnacles with an average of 117±195 barnacles per shell, as well as 169 additional organisms (Figure 6). On average 20±29% of the shell hash surface was covered in barnacles (Figure 7).

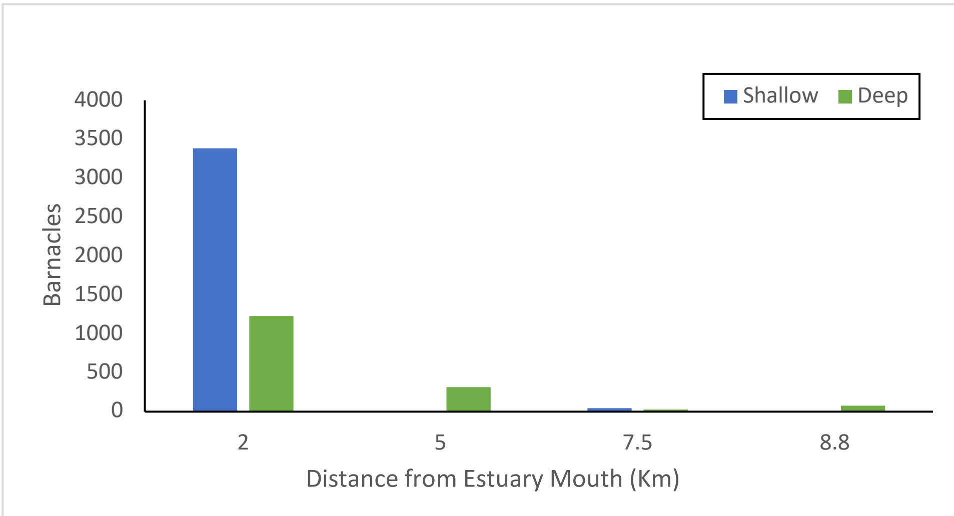

Figure 5: Total Barnacles found on shell hash at each site recovered in November trawls.

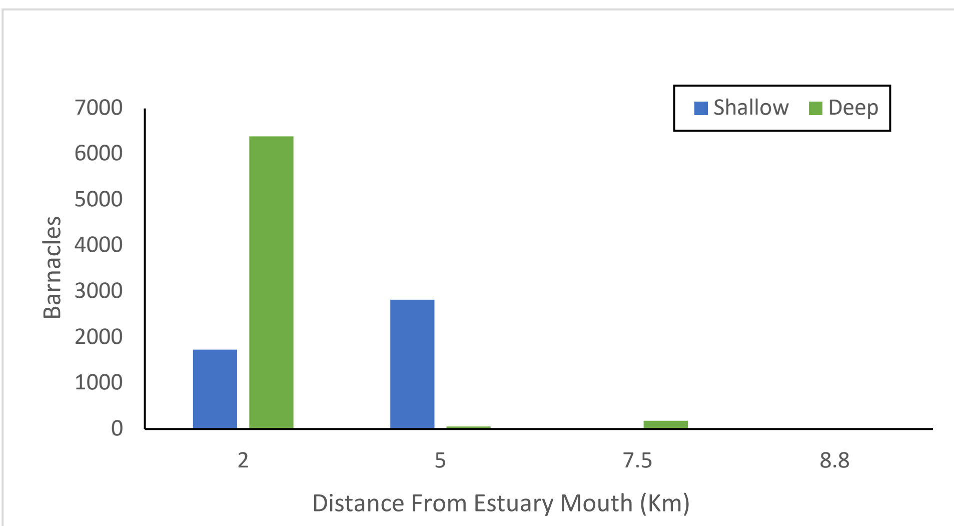

Figure 6: Total Barnacles found on shell hash at each site recovered in February trawls.

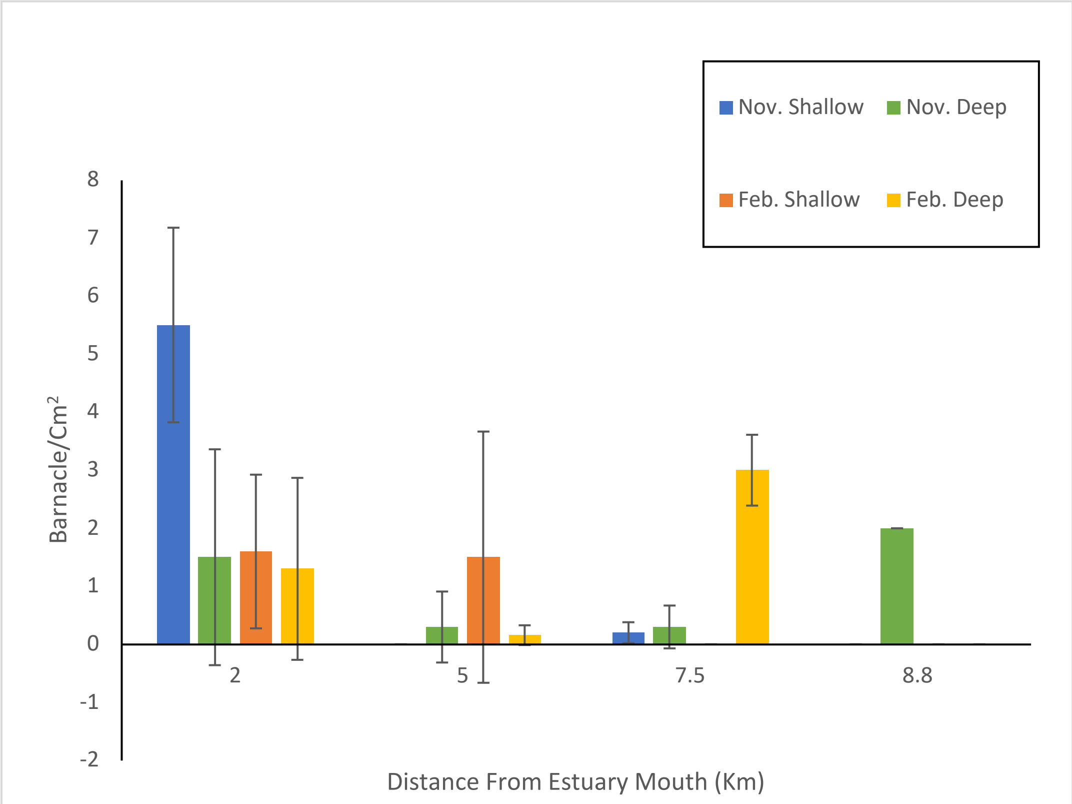

Figure 7: Average barnacle cover per centimeter squared from shell hash at each site with standard deviations.

In both the November and the February samples, there was no strong correlation between the total shell hash area recovered or the distance from the estuary mouth (Table 3). Similarly, there was no strong correlation between either the number of barnacles found and the total shell hash area, nor the number of barnacles found and the distance from the estuary mouth. The total number of individual shells found within the shell hash was correlated to total shell hash area sampled and negatively correlated to the distance from the estuary mouth.

Table 3. Correlation coefficients for shell hash area, number of barnacles, distance from estuary mouth and number of individual shells. Coefficients from both samples are presented in November/February format.

Variable	Shell Hash Area	No. of Barnacles	Distance from Estuary Mouth	Individual Shells
Shell Hash Area	-	0.674/0.561	-0.405/-0.0622	0.914/0.997
Number of Barnacles	-	-	-0.510/-0.126	0.796/0.993
Distance	-	-	-	-0.989/-0.957
Individual Shells	-	-	-	-

In addition to barnacles, the February shell hash also had 90 other organisms present (Figure 8). The individuals were made up of 8 different species across 7 different animal phyla. The phyla represented were Annelida, Cnidaria, Porifera, Arthropoda, Mollusca, and Bryozoa. There were also red algae present. Not counting Arthropoda, represented by barnacles, Bryozoa was the dominant phylum of the remaining organisms with 51 colonies. Rhodophyta was the next most common with 11 individuals, and Porifera and Arthropoda both only had a single individual. Bryozoans were found on 54% of the 95 pieces of shell recovered from the survey.

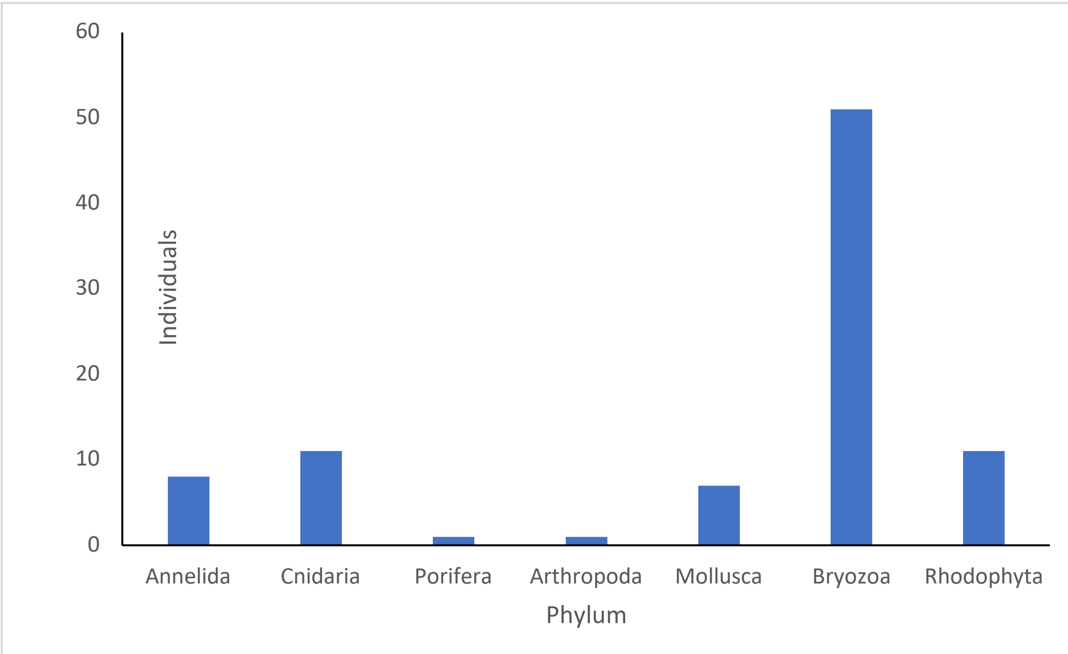

Figure 8: Organisms found on shell hash, other than barnacles. Individuals were separated by phylum. Barnacles are removed from this dataset to allow for distinctions in other phyla to be visible, as barnacles outnumbered other organisms by several orders of magnitude.

Trawl Organisms

The trawl samples from the November sampling session yielded 317 individuals (six phyla). The number of organisms captured during sampling ranged from 1 individual during the shallow trawl at Area 4 to 119 in the shallow Area 3 trawl. Individuals from Arthropoda, Chordata, Cnidaria, Echinodermata, Porifera, and Annelida were all present in the trawls (Figure 9). Arthropoda was the most abundant phyla in the trawl (204 individuals) and Chordata was the second most abundant (83 individuals). Annelida was the least represented, with a single organism found within the trawl. The February trawl yielded 210 individuals (seven phyla). February sampling ranged from 1 individual in the deep trawl at Area 3 to 89 individuals at the deep trawl of Area 4. Individual species from Arthropoda, Chordata, Cnidaria, Echinodermata, Porifera, Mollusca, and Nemertea were present in the trawls (Figure 9). Arthropoda was the most abundant (96 individuals) and

Chordata was the second most abundant (56 individuals). Nemertea was the least represented with a single organism captured in the February trawls.

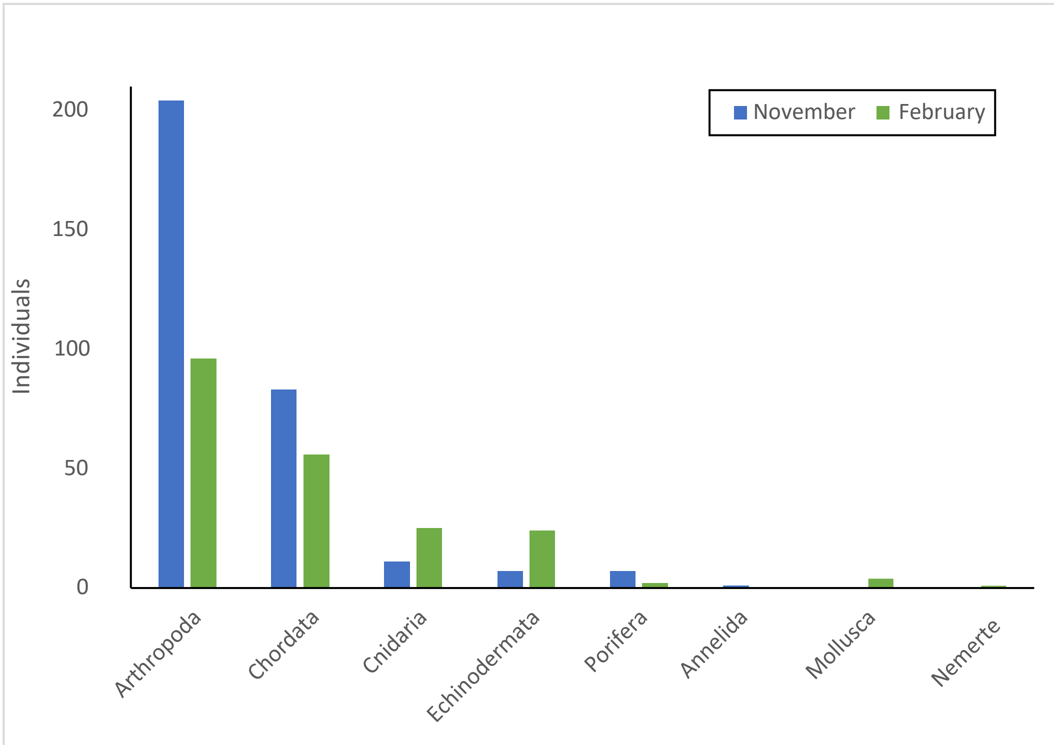

Figure 9: Composition of trawls, separated by phylum.

Three species dominated the samples. In both the November and February samples Dungeness crab, *Metacarcinus magister*, English Sole, *Pleuronectes vetulus*, and Smooth Bay Shrimp *Lissocrangon stylirostris* were found in far greater numbers than any other species. In the November trawls there were generally more organisms found closer to the mouth of the bay. In the February trawls individual organisms were found further into the bay, with more organisms found at Area 4 than any other site. However, due to technical difficulties and a damaged trawl, only a partial sample of Area 1 was achieved in February. *Lissocrangon stylirostris* were the most abundant organism found in samples from both sample dates, with a total of 217 individuals (144 Nov, 73 Feb). *Pleuronectes vetulus* was the second most common organism found during the trawls with 124 individuals recovered across both samples (Nov 79, Feb 45). *Metacarcinus magister* was the third most common organism captured during the trawl samples. Seventy-four total individuals were captured across both sampling sessions (Nov 52, Feb 22).

Table 4. Number of individuals of *Lissocrangon sylirostris, Pleuronectes vetulus, and Metacarcinus magister* found at each site.

	Lissocrangon sylirostris		*Pleuronectes vetulus*		*Metacarcinus magister*	
Area	November	February	November	February	November	February
1: Shallow	18	0	9	1	10	0
1: Deep	10	0	13	0	13	0
2: Shallow	13	5	7	8	4	1
2: Deep	12	1	6	0	4	0
3: Shallow	73	16	37	13	9	7
3: Deep	1	0	36	0	3	0
4: Shallow	1	8	0	2	7	0
4: Deep	16	43	7	21	14	14

Lissocrangon stylirostris was consistently found in greater numbers further into the bay during both samples, followed by *P. vetulus*, and *M. magister*, respectively (Table 4). Site 3 had the most individuals for both the *L. stylirostris* as well as the *P. vetulus* than any of the other sites. November and February surveys had different distributions of organisms, with November individuals being found with an increasing frequency near the mouth of the bay and February individuals found the further from the mouth. February had more individuals found at every subsequent site, with Area 4 having the most of any individual found.

A 2-factor ANOVA was run comparing depth and distance from the mouth of the estuary for each of the three organisms *M. magister*, *L. sylirostris*, and *P. vetulus*. No significant results were found. Correlation coefficients were calculated between the number of each s species and depth and distance to determine if they were significant, which they were not (Table 5).

Table 5: Correlation coefficients for depth and distance from the November and February trawls. Values are presented in the format November/February.

Variable	*M. magister*	*L. sylirostris*	*P. vetulus*
Distance	-0.561/0.525	0.109/0.604	-0.055/0.526
Depth	0.520/0.451	0.207/0.478	0.385/0.424

Correlation coefficients were also calculated to determine if the presence of any of the three species was significantly correlated to the others (Table 6). During the November trawls there was a significant correlation between the presence of *P. vetulus* and *L. stylirostris*.

Table 6: Correlation coefficients of significance between the presence of species. Values represent both samples in the format November/February.

	M. magister	*P. vetulus*	*L. sylirostris*
M. magister	-	0.540/0.958	0.390/0.973
P. vetulus	-	-	0.967/0.937
L. sylirostris	-	-	-

It is unclear whether this is a response of similar habitat needs of the species or if the species have a more interconnected relationship. The findings implicate habitat conditions as somewhat determinative of individual location. The counts of these three organisms all showed significant correlation between each other during the February trawls with correlation coefficients of over 0.95, while showing a different pattern in November.

Discussion

The grab samples proved difficult to employ during the survey and did not yield many organisms at any site. Consistently across all sites there seemed to be very little infaunal activity within the sediment of the bay. While on its face it shows that there is not much life, there may be other explanations. Certainly, the small size of the sample was inadequate to draw any meaningful conclusions. With a sample size of one it is hard to draw any conclusions as to the richness of the infaunal community of the bay. The Ponar grab was not able to adequately sample sites 1 and 2 due to the sheer amount of shell hash present in these areas. While the shell hash provided additional substrate for organisms to inhabit, it effectively prevented collection of full sediment samples. Since site 1 had the greatest number of individuals even with a very small sediment sample, further surveying is necessary. Using either a larger Ponar grab that can sample the sediment as well as the shell hash, or another type of grab more suitable for dealing with shell hash would allow for researchers to take a more representative sample of the sediment at site 1 and 2. Additionally, the small size of the Ponar grab frequently made it difficult to use in the strong currents of the bay. When deployed from the side of the boat, it would often become caught in the current, causing it to land slightly sideways. This was often enough to prevent the spring holding the jaws open from releasing. Due to time constraints, researchers were frequently forced to take meager sediment samples back to the lab for processing. When conducting future surveys, it would be beneficial for the volume of the samples to be taken, to provide a better understanding of the relative density of infaunal organisms.

The planned dredging areas within the channel all appear to be a similar mud to muddy sand habitat under the influence of the large tidal range of the bay. In addition, the channel regularly undergoes maintenance dredging, which affects all of the sampled sites. Given the similarity in habitat, the similar communities found throughout the bay were expected. The flatfish *P. vetulus,* was routinely captured by the trawls. Similar to *P. vetulus*, other fish that were captured exhibit similar ground-resting behavior, allowing them to be captured by the otter-trawl. It is likely that a dredging operation such as the one proposed would kill all of the ground-resting fish within the dredge area. *M. magister* and *P. vetulus* exhibited similar distributions, with more individuals being present near the mouth of the bay in the November sample, and the further into the bay in the February sample. While there were minor seasonal differences between the sample dates, generally I observed a similar community composition throughout the survey period and across samples sites; the planned dredge area is used as habitat for a similar community. The channel appears to provide habitat connectivity allowing organisms to traverse the bay while remaining in a continuous similar habitat. The similar habitat and connectivity of the channel result in a functionally contiguous population that inhabits the bottom and sides of the channel.

In contrast, the shell hash habitat was not present equally. The shell hash was more abundant near the mouth of the estuary. While shell hash was still present in the upper bay, it was also occupied by fewer epifaunal organisms. As one would expect, larger shells tended to have more barnacles on them. While it stands to reason that a larger shell would have more space for barnacles to settle on, and may not be buffeted around by the currents, it seems that the entrance to the bay provides better habitat than further into the estuary. This could be because of the direct access to the bay provides better food availability for the coastal barnacles that settle on the shell hash and provide better habitat than further into the estuary. Additionally, the flow of the likely deposits shell hash in similar areas with the predictable tidal flux. Greater amounts of shell hash were found in Area 1 where the estuary makes an abrupt turn northwards. The hydrodynamics of this area could serve as a collecting area for shell hash, providing a perfect settling environment for barnacles and other organisms. Dredging activity in site 1 and 2 would likely eradicate the shell hash community present within the planned dredge sites. Due to the abundance of individual organisms found on the shell hash it is difficult to determine the effect this may have on the larger ecosystem. Organisms surveyed that live on shell hash and eat barnacles, such as the barnacle-eating nudibranch *Onchidoris bilamellata* would certainly be affected either by direct mortality or a reduced amount of prey species. However, further research is necessary to determine the replenish and resettlement rates of shell hash and barnacles near the entrance of the estuary. By understanding how quickly shell hash is built up within the bay, a determination of the impact the dredging could be made.

While the community in the channel environment is composed of a diversity of species, Dungeness Crab, English Sole and Smooth Bay Shrimp appear to dominate the community. The potential damage to these populations within the bay must be acknowledged by the JECP's dredging action. Due to the unique nature of the channel habitat within the bay, this survey could reflect such high numbers of these specific organisms because much of their populations within the Coos Bay estuary are concentrated within the channel. If this is the case, major dredging action within the channel may have a larger than intended effect on the community within the estuary. Maintenance dredging does occur every 10 years within Coos Bay, but the excavation dredging for this project would be significantly more extreme. It is likely that any organism that could be caught in a small trawl would also be caught in a dredge, resulting in the mortality of any organisms living in the dredging areas. Beyond the individuals harmed, this could affect multiple trophic levels as the numbers of prey and predator species associated with these organisms could fluctuate.

The population of some organisms within the study, namely *Metacarcinus magister*, was additionally reduced by constant fishing within the bay. It is unknown whether the reduction due to fishing had a more than a negligible impact on the results of this study. While differences in numbers and locations of *M. magister* between sampling dates may be due to natural fluctuations in the populations, they were also likely influenced by the presence of crab pots usually found around the Area 1. While crab fishermen utilize the bay around all four areas for their catch, they were more commonly seen by researchers around sites 1 and 2 than 3 and 4. However, this could also have very little effect on the numbers seen. Fishermen are only allowed to take crabs above a certain size, while this survey noted *M. magister* of any size, provided they were large enough to be captured in the trawl. Additionally, the distribution of *P. vetulus* and *L. sylirostris* both exhibited a similar trend to *M. magister* throughout the bay despite not having the same pressures from fishing. The constant removal of species due to fishing on *M. magister* may suggest that fewer crabs are located at the mouth of the bay than would be expected to be found there. If catch counts could be established, the potential ramifications to the crab population could be better understood.

This project could benefit from the collection of additional data. The trawl sampling focused on the in-water work window for the JCEP. By surveying the sites outside of the work window seasonal migrations, if they exist, within the channel could be better understood. This could help the JCEP to choose a dredging time that would have the least impact on the bay. Additionally, the project would benefit from grab samples being taken during any trawl sampling sessions. This would also need to be accomplished with a much larger grab to compensate for the flow of water and shell hash cover within the bay. Having more data about infaunal organisms would be beneficial to understanding how diverse the benthic community is. Staining and processing samples could also help to ensure that that all organisms captured are counted by the study. Additionally, in lieu of grab samples, a resettlement experiment could be run to test exactly how rapidly the main channel will recolonize after a removal event, which would provide better data for the aims of this project.

Maintaining consistent processing procedures would benefit multiple parts of this study. For example, due to the different shell hash processing methods, it proved difficult to compare the November and February data. While the barnacle data are reliable for both sample dates, because the November sample were dried before processing it was not possible to identify epibiota living among the barnacles. A consistent processing method would serve to create a deeper understanding of the epibiota that makes its home on the shell hash.

In future surveys water data should be taken at the same time of the trawls, and the trawls should be spread throughout the year. This would allow researchers to explore whether organisms were moving around the estuary in a response to a change in temperature, salinity, or some other reason. This information, coupled with the hydrodynamic data of the estuary could help to the JCEP pick a particular dredging time that may be less detrimental to benthic populations. Due to the scale of the project, however, this may still be impossible, or impractical.

Finally, it is recommended by the researcher that further data collection not occur during a global pandemic, if it can be at all avoided. Due to restrictions from COVID-19, this project was hindered by boat captains leaving the organization, boats breaking down, equipment failures, huge wait times for parts and labor, social distancing concerns, incessant mask fog blocking sunglasses, and general uncertainty. Only with perseverance and an amazing support team was any data collected, but in the future with a set collection schedule and standardized equipment, more consequential trends may be observed.

This project highlights the nature of combining science and legal work. In order for this survey to have any meaningful use within the context of the responding to the JCEP, it would need to be completed and submitted within the 45-day notice and comment period. While difficult, this project demonstrates what can be accomplished with limited resources and a reduced crew. While it is possible to complete supplementary science within a shortened window, whether it can be peer reviewed and published in that time is another issue.

CHAPTER III: Comparison of existing eelgrass habitats and communities in the proposed removal and transplant areas

While most of the planned dredging activity for the JCEP (Jordan Cove Energy Project) will occur in the existing navigation channel, part of the plan includes the construction of a slip that will enable tankers to attach themselves to the terminal for the onboarding of LNG (Liquified Natural Gas). This access channel would connect the JCEP to the navigation channel (Figure 16). In front of the planned Jordan Cove site, where the access channel will be dug, there is a large eelgrass meadow which will be destroyed during construction. *Zostera marina* is recognized as an important habitat for many organisms and an essential nursery habitat for many marine species, including fisheries species of commercial importance (Jackson et al. 2001). Due to federal and state protections for essential fish habitat and eelgrass, the JCEP has crafted a mitigation plan that seeks to minimize the damage caused to the estuary. They have proposed a mitigation plan to offset the planned destruction of eelgrass habitat by transplanting eelgrass from the current bed that would be destroyed to a site across the bay, south of the airport runway (Figure 16). Currently there is a large eelgrass bed south of proposed mitigation site, and the JCEP plan calls for an expansion of eelgrass into suitable habitat near this bed. The area of the mitigation zone is currently a mixture of subtidal and intertidal mudflats covered with patches of eelgrass. The plan calls for lowering the existing estuary bed to a uniform subtidal depth to create 10 new acres of suitable eelgrass habitat. Within this prepared area the JCEP will transplant 3 acres of eelgrass from the dredging area and the mitigation zone (FERC 2019). The two acres of eelgrass that are in the path of the dredge would attempt to be transplanted from the planned access channel. Supplemental eelgrass will be transplanted from a donor patch southwest of the mitigation zone until a total of three acres of eelgrass has been successfully transplanted. Depending on the method of transplant and area conditions, eelgrass transplantations can have varied degrees of success (Park and Lee 2007).

The survey described here was undertaken in order to compare the eelgrass bed within the planned dredge access channel area (JC) and the airport mitigation zone (Airport). I used this survey to evaluate the relative habitats within the two eelgrass beds in order to determine whether the eelgrass community in the dredging site and recipient beds are similar. Additionally, the survey was used to determine whether comparable ecosystem services would be provided in the mitigation area to those already present in the access channel bed. As a measure of potential differences in the animal communities, I compared eelgrass shoot density and blade sizes between the two beds, as well as evaluated the epibiotic fauna on the blades.

Methods

Two separate eelgrass patches were surveyed, one within the area of the planned dredging for the JECP access channel and one currently present in the mitigation zone southeast of the airport. The surveyed areas were chosen based on their inclusion within the JCEP plan. The ‘donor’ patch is south of the planned LNG plant, while the mitigation zone is across the channel to the south of the airport (Figure 10).

I sampled along three 50 m transects at each of the two sites, JC and Airport. To determine area coverage, shoot density was measured along each of the transects using five randomly placed 25 cm^2 quadrats divided into 9 even sections with twine, numbered in identical positions to a telephone keypad. A random number generator was used to determine where along the transect each quadrat would be placed. Upon arriving at a site, a tape measure was placed 1 m from the shore edge of the eelgrass bed and then extended 50 m parallel to shore. The quadrat was then placed at the first random position on the transect. I counted the number of shoots growing within the boundaries of each quadrat.

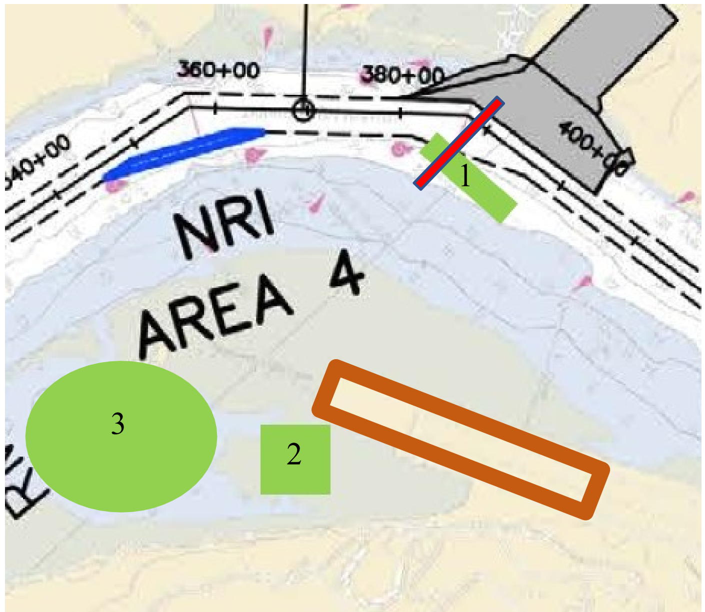

Figure 10: Detail of area surrounding the Jordan Cove Energy Project which is highlighted in gray. The Coos Bay airport runway is highlighted in an orange outline. The two green boxes represent the approximate locations of the affected eelgrass beds. 1 represents the transplant bed. 2 represents the mitigation zone. 3 represents the donor patch. The red box shows the location of the access channel to the terminal. Dredge Area 4 is visible

Following shoots counts, I harvested individual blades from sections 1, 3, 5, 7, and 9 of each quadrat. The tallest standing blade from each shoot was harvested at the sheath (Figure 11). If shoots were not present in these five sections, five representative blades were chosen as available. If there were not enough shoots present to retrieve five separate samples, as many sample blades from distinct shoots were taken as were available. Blades from each quadrats were placed in bags and transported to the lab for analysis. After five quadrats were completed along the transect, the tape measure was moved 5m deeper from the previous transect and the sampling process was repeated. A total of three transects were sampled at each site, 1m, 6m, and 11m from the shore edge of the bed. The Jordan Cove site was measured first, and the same procedure was repeated at the Airport site.

Blade samples were processed individually. The length and width of each blade were measured, and the total blade area was calculated using L*W*2 for the total area on the larger face of the blade. The total eelgrass blade surface area for the samples from each quadrat and transect was calculated. Epibiota found on the blades during this process were counted and identified to the lowest possible taxonomic unit.

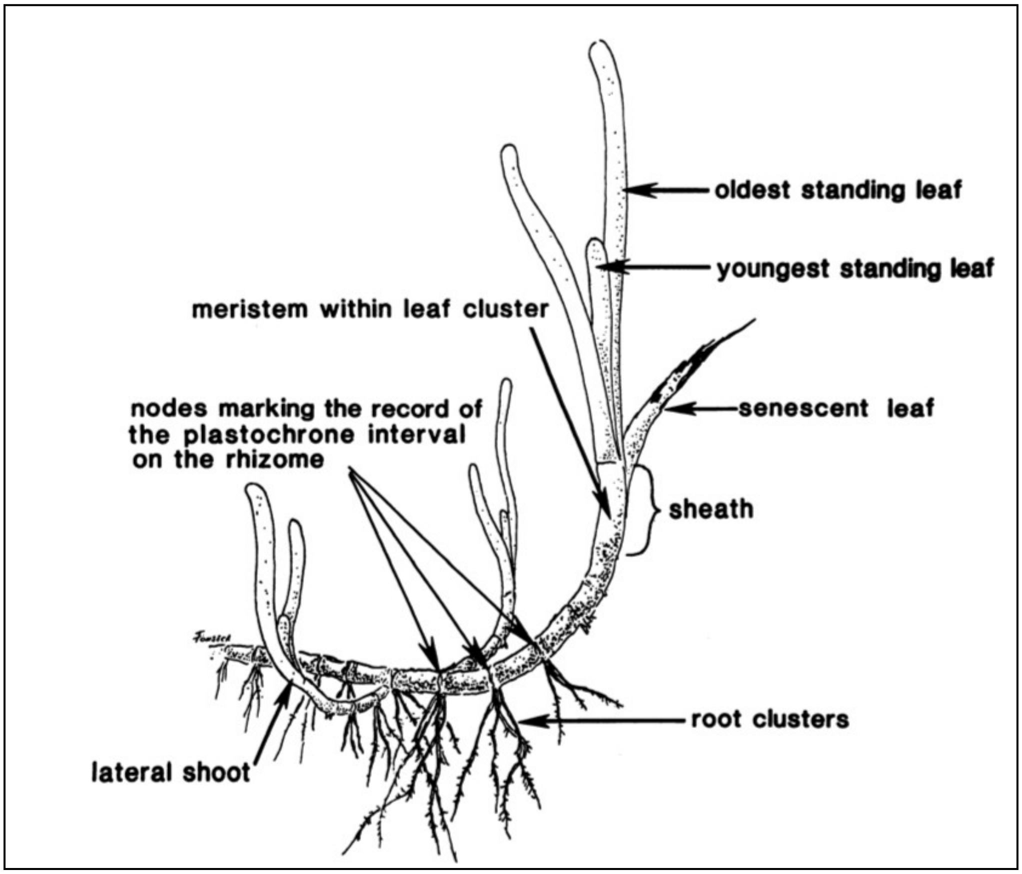

Figure 11: General morphological features of *Z. marina*. (Thayer et al. 1984).

<u>Results</u>

Shoot Density

The eelgrass bed within the proposed JC access channel had more contiguous eelgrass than the patchier Airport bed. The overall shoot density between the two sites was significantly different (Figure 12). The JC bed was found to be significantly denser than the Airport site. At the JC channel access site, a single quadrat had zero blades, while at the airport site there were eight empty quadrats. At the Airport site, each transect had at least two successive quadrats where zero shoots occurred. Additionally, transect two at the Airport site had a gap where three consecutive quadrats lacked any shoots. The maximum number of shoots observed within a single quadrat at the JC site was 10 while the maximum at the Airport site was 8. The

JC channel access bed had an average shoot density of 4.5±3.2 shoots/25cm^2 (standard deviation) while the Airport transects had an average shoot density of 1.9±2.5 shoots/25cm^2. Shoot density was found to be significantly higher at the JC site (two-sample t test=2.042, n=30, P=0.019).

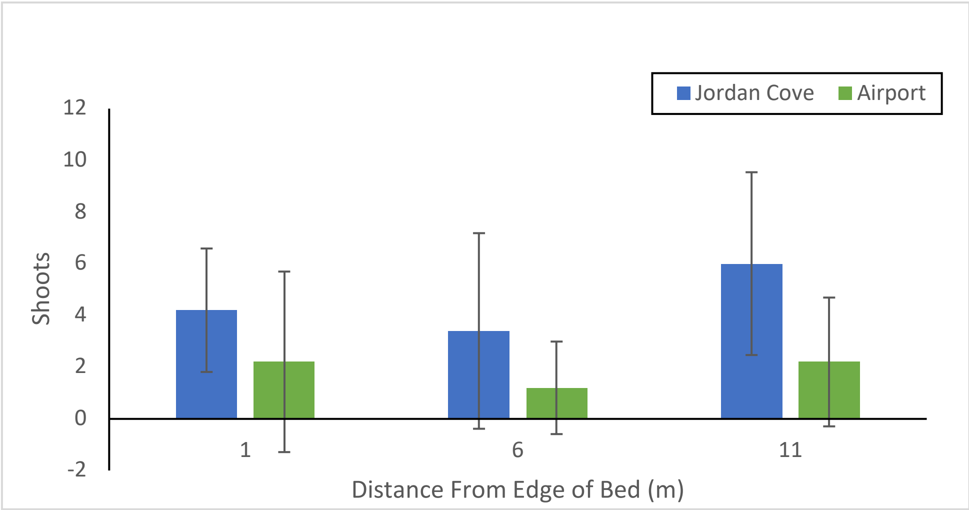

Figure 12: Averages and standard deviations of shoot density of each plot separated by distance from the edge of the shore side of each eelgrass bed. Blue bars represent the Jordan Cove dredge site, while the orange bars represent the Airport mitigation zone.

Blade Area

The overall blade area was significantly greater in the Jordan Cover area than the mitigation zone (Figure 13). A total of 74 blades were collected across both sites, 50 from the JC site and 24 from the Airport site. The blades ranged in width at the JC site from 0.4mm to 1mm with an average of 0.71±0.15mm, and from 0.4mm to 0.8mm at the Airport site with an average of 0.57±0.10mm. Overall the samples had an average blade width of 0.66±0.15mm. The average blade length was 35.1±16.5mm at the JC site and 26.6±8.04mm at the Airport site. The average length of eelgrass blades across all sites was 30.9±14.8mm. The total average blade area at the JC site was 51.8±31.2mm^2 while the average blade area at the airport site was 22.9±18.6mm^2. Blade area was found to be significantly higher at the JC site (two-sample t test=1.990, n=74, P<0.001).

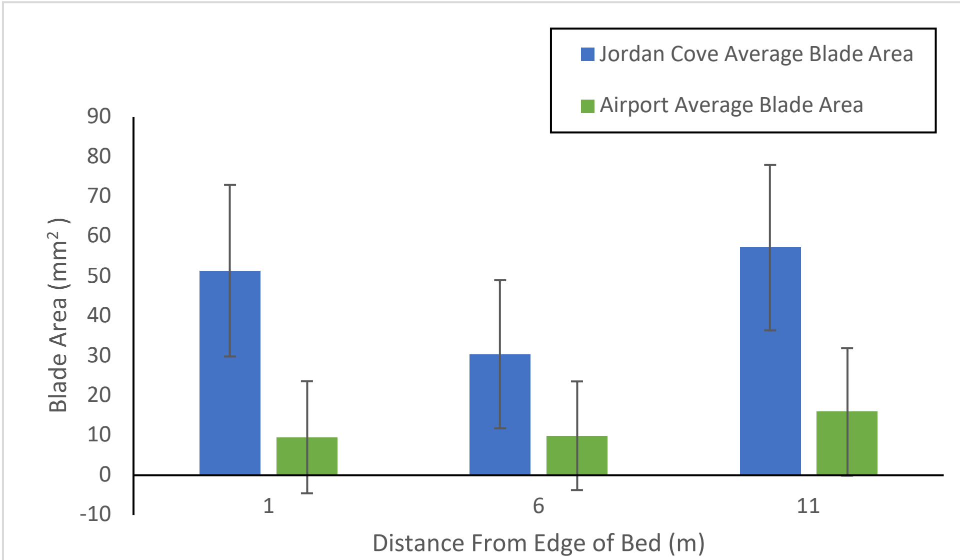

Figure 13: The average blade area and standard deviation found across samples from each site. Blue bars represent the Jordan Cove access channel, while orange bars represent the mitigation zone.

The communities at both sites were dissimilar (Figure 14). A total of 19 organisms were found between the two sites. 5 taxa were found at the JC site and 14 at the Airport site. The most common phylum at the JC site was Arthropoda while the Airport site was dominated by Mollusca, representing markedly different communities of organisms. Snail egg masses were found at both sites, however, many more were present at the Airport (4 and 48, respectively).

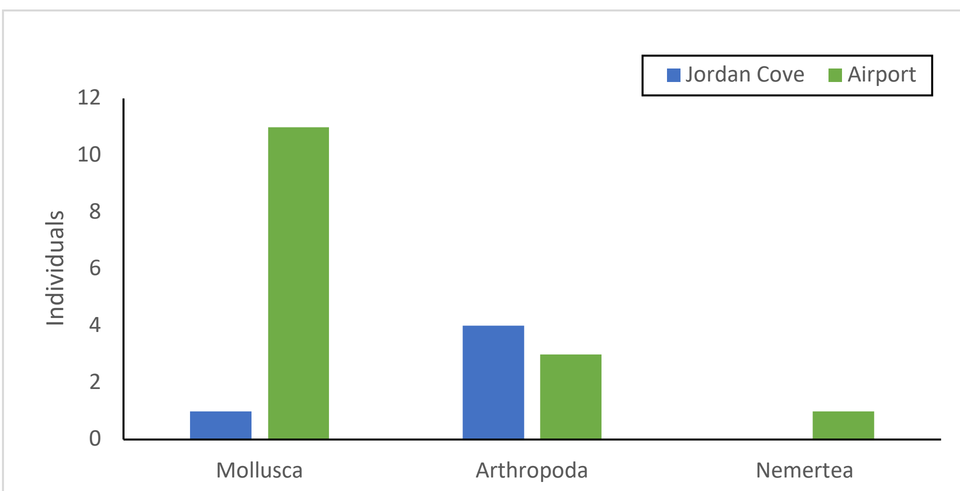

Figure 14: Phyla present at each of the sites sampled. Figure represents richness of phyla at each site.

At the JC site, of the 5 total organisms were found, one *Lacuna porrecta*, . Three eelgrass isopods, *Idotea resecata*, and one *Ampithoe lacertosa*. Of the 14 organisms present at the Airport site, 11 were *L. porrecta* and three *A. lacertosa*. A single ribbon worm *Amphiporus imparispinosus* was also found within sediment that had settled on the blades, marking the only instance of phylum Nemertea found by the survey.

Discussion

The JC and Airport eelgrass sites are distinct from each other in both their bed composition and the associated communities living there. The shoot density at the JC site was over two times greater than at the airport site and shoots were less patchy. Since *Z. marina* usually reproduces asexually by spreading rhizomes through the sediment to form a thick mat, this suggests a denser mat is present at the JC site. Three quadrats at the JC site had only a singular shoot present, which likely connected to nearby shoots through the tendrils of rhizomes snaking through the sediment. The airport site exhibited larger continuous gaps without any shoots. The quadrats were randomly placed, so the survey method could have missed shoots occurring between the transects, but multiple quadrats without any shoots provides evidence for a less dense rhizome mat than at the JC site. While the JC site had more densely packed individuals, the longer blade sizes suggest a more established population of *Z. marina* with more potentially more advanced rhizomes, or overall healthier plants. Once eelgrass matures it begins to spread rhizomes and extend lateral branches (Thayer et al. 1984). The presence of more small shoots suggests new either new growth or expanding plants. In either scenario the Jordan Cove site is experiencing biomass growth not seen at the airport site.

Both blade area and shoot density was shown to be significantly larger at the JC site with two sample t-tests. There was both a greater number of shoots and larger blades at the JC site suggesting a more mature eelgrass bed than the area surveyed at the Airport site. The lower blade area provides less surface area for epibiota . Furthermore, the Airport site had smaller blade lengths than the JC site, limiting the amount of habitat available for other species to use either as a nursery or hunting grounds. The number of fish present in an eelgrass bed has been found to be directly correlated to the total biomass of the eelgrass present (Adams 1976). This is affected by both blade size and shoot density, as longer blades growing closely together will greatly increase overall mass.

While not quantified, the blades at the Airport site were covered in sediment while no instances of sediment covering the blades at the JC site were observed. This was associated with a shift in the communities present on the blades, with a greater abundance of Lacuna snails and an absence of isopods. While it is unknown whether the blade sedimentation, the area available, or some other combination of factors is responsible, the communities found at each site were distinct. The JC site was dominated by arthropods, with eelgrass isopods found on the blades. Blades covered in sediment are brown rather than green and may prevent the isopods from laying their bodies flush along the blade. Additionally, the sediment likely would make it more difficult for the arthropods to grasp the blades. Sedimentation of the blades reduces the habitat quality for these arthropods that are common in other parts of the bay. Based on the community currently present at the Airport site, if the arthropod-dominant eelgrass beds are transplanted to an area where heavy sedimentation is likely, it is probable that they will not experience the same habitat benefits as they did pre-transplant. The sedimentation was present in a habitat dominated by Mollusca, as well as other species not often associated with eelgrass beds. While snails and egg masses were often found on the blades of the Airport site, only a single snail was found at the JC site. A single instance of a species usually associated with mudflats, *A. imparispinosu*, was found, at the airport site. (Hiebert 2015).

The differences of the blade communities may reflect other factors present in the bay. Despite being spatially close to each other within the estuary, the planned dredge area of the JC channel access site probably experiences different environmental conditions than the Airport mitigation site. The JC site is positioned at the corner of the main channel. As a result, it has large volumes of water flowing through it with the tides. In contrast, the Airport site is more protected from direct water flow by the airport runway. This shelter provides a protected area for fine sediments to settle resulting in the sediment of the Airport site being much finer than that of the JC site and likely is the cause of the fine deposits of mud present on many of the blades from the Airport site. The sediment classification of the JC site is fine sand, while the protected area of the Airport site is mud (USACE 2009). A hydrodynamic model of Coos Bay shows that salinity remains higher in the area of the Airport mitigation zone than the JC patch, possibly influencing the different communities present in the eelgrass (Sutherland 2019). Due to higher salinity and sedimentation, lower water flow and other associated factors, it is expected that the habitats available at each site would be distinct from each other. Because the communities support different phyla, the two sites likely have different ecological roles within the estuarine food web. Thus, simple transplanting does not necessarily capture the habitat that is being removed.

The different communities present at the two sites have different habitat requirements, and it is not guaranteed that the epibiont community will resettle effectively to the new habitat. Depending on the foraging needs of larger species within the bay, transplanting arthropod-dominant eelgrass to an area dominated by Mollusca and species associated with mudflats could reduce the amount prey species available. Predator species relying on the communities present currently at the JC donor site may not be able to utilize the Airport mitigation zone to the same extent, especially if it relies on a prey species not found there. Because eelgrass is a key nursery habitat for many species, a change to the assemblage of prey species in the bay could have an outsized effect on some of the larger species within the bay. Some of these species that use the Coos Bay eelgrass beds for their hunting grounds are commercially important, such as Rockfish, and any potential impact to their habitat should be carefully evaluated (Dauble et al. 2012). When evaluating the success of the transplant, it will be important to survey the communities the transplantation is supporting and ensure that similar prey communities are still present.

The JC and Airport sites are distinct in their physical make up as well as the communities that utilize them as habitat. The continuity of the JC site provides added habitat connectivity that is not present at the Airport site. This provides less available habitat for organisms that live on the blades, as well as less cover for larger transient species that are may use the eelgrass as nursery habitat. The significant differences between the two sites suggest that it is unlikely that transplanting eelgrass to the Airport site would replicate the removed eelgrass from the JC site. Even with a successful transplantation, the growth rates will not be similar, *Zostera marina* growing in the Airport mitigation zone are unlikely to reach the same blade size or density that is found at the JC donor patch. With different growth rates and external conditions, maintaining the current communities within the bay will likely be more complicated than simply moving a seagrass bed. In order for parity between the two beds to be achieved, further surveys and careful monitoring will be necessary.

Any present comparisons between the sites must consider the planned modifications to the mitigation zone stated within the JCEP. The current Airport bed exists at a depth that is partially exposed at some low tides. The plan acknowledges that this not an ideal habitat for *Z. marina* and includes an additional dredging plan to lower the mitigation zone to a suitable depth. Then, after transplanting two acres of eelgrass from the JC site, the JCEP will transplant between 1-3 acres of eelgrass from the “donor” patch 1,500ft to the south west (FERC 2019). This survey does not evaluate any potential issues of combining transplantation from different sites and does not address the logic behind digging up a healthy eelgrass bed and moving it 1,500ft in the name of “mitigation”. The lowering of the estuary to establish more suitable habitat for eelgrass would eradicate the individuals currently there, along with any rhizome mats that lock in the muddy sediment. Whether or not this will provide a suitable habitat for a new eelgrass bed, or if it will become choked with sediment remains to be seen. With the sedimentation observed and hydrodynamics of the bay, it is not beyond reason that the mitigation zone will become chocked with sediment and revert to its previous intertidal state.

It is unknown how large the overall impact to the bay will be based on the likely community shift and change in eelgrass habitat type. There are eelgrass beds, namely the ‘donor patch’ present in the bay that may be large and healthy enough to support the needs of entire estuary. However, to rely on this reasoning contradicts the idea that the transplant is serving any sort of mitigation. Instead, the JCEP’s plan seems to be to eradicate two beds and weaken another removing up to a total of 5 acres of viable eelgrass in the first round of transplanting alone, if the 2 transplant acres were deemed unviable. This is done in the name of creating 3 acres of viable eelgrass in an area with different conditions than the desired habitat. If the first transplant is not successful, this could result in further eelgrass acreage being removed from the donor patch, still in the name of mitigation. There is also potential for the eelgrass habitat to be prematurely declared a successful transplant. The mitigation plan calls for 5 years of monitoring, however, research has indicated that it can take up to three decades for recovery to occur (Tomasko et al. 2018). While that time scale can often be lowered to ten years, it is generally necessary to continue monitoring an eelgrass bed for at least 5 years longer than the JCEP allots to assess the success of a mitigation. .

This survey could benefit from additional research. It would be valuable for the ‘donor’ site to be surveyed as well, since this patch southwest of the airport will be partially dug up for transplantation to the mitigation zone. From visual observation it is much denser than either the JC or the Airport sites. It would be helpful to understand how the donor patch compares to the other two sites in terms of shoot density and blade area. This would give a better understanding of the comparable health of the three sites. Additionally, it would be helpful to know what epibiont communities are present within the donor patch. The donor patch sits far closer to the flow of the main channel. If the organisms present in the donor patch are more like the JC site, then evaluations should be made as to whether it makes sense to move multiple existing communities into a potentially less hospitable area, instead of assessing means of expanding the donor patch itself.

A second recommendation is to collect more samples from each site. Having data from only three transects at each location provides a preliminary picture of the two sites, but with more data, further trends could be evaluated. My small sample size probably was insufficient to find all or even most of the species present at the two sites. Additionally, rhizome samples should be collected from each site so as to allow for comparisons to be made of their density. This would help to determine the relative health and age of the beds and see if the shoots present are mostly new growth, or new shoots from the same plant. Similarly, sediment samples should be taken from each site. A quantitative evaluation of sediment particle sizes would permit more rigorous comparisons of the habitats in the two sites. Finally, the total amount of sediment fouling the blades should be measured to understand how much habitat is lost or gained (depending on the species) by sedimentation. .

Although they are situated close to one another within the Coos Bay estuary, the planned dredge area for the channel access to the JCEP and the airport mitigation zone are distinctly different beds of eelgrass. In general contiguousness, average shoot density, blade size, and overall blade area, the JC site, destined for possible destruction, appears to be a healthier bed than the Airport site. Similarly, the two sites have a different epibiont community, dominated by different taxa. While they may seem interchangeable on a map, once you dive below the surface it quickly becomes apparent that the two sites are dissimilar. Because my study focused on only the blade fauna, it does not reveal much about the extended communities of organisms that use the eelgrass beds as habitat. These include motile organisms, both benthic and pelagic, that use the beds for food and shelter, as well as infaunal organisms that probably comprise the majority of the fauna. An extended sampling protocol using seine nets and rhizome cores is needed to evaluate the larger impact of the proposed mitigation plan. Even the preliminary data reported here, however, raise concerns that the transplant site will never be as productive in terms of biomass or ecosystem services as the site that will be removed.

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