Bull Kelp (*Nereocytis luetkeana*) Monitoring & Enhancement Plots

Prepared for: Environment and Climate Change Canada

Prepared by: Mount Arrowsmith Biosphere Region Research Institute (MABRRI),
Vancouver Island University

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1.0 INTRODUCTION

Environment and Climate Change Canada provided three fiscal years of funding (2017 – 2020) to the Mount Arrowsmith Biosphere Region Research Institute (MABRRI) at Vancouver Island University (VIU) in January 2018. Ultimately, this grant would provide funding for two seasons of bull kelp (*Nereocytis leutkeana*) planting.

MABRRI sought after this funding in order to re-establish bull kelp forests in areas of the Central Strait of Georgia that were once rich with bull kelp, however now have little to none left. Bull kelp populations in the Central Strait of Georgia are at an all time low, which is thought to be the result of increasing water temperatures and grazing pressures (Macrae, 2018). As bull kelp forests have proven to be incredible ecosystems for a number of reasons, it is projects like this one that are working towards their preservation and conservation that are incredibly important.

This report will outline the importance of bull kelp in the Strait of Georgia, the main objectives of the project that MABRRI undertook, the methods used, initial results, and a brief discussion on the project and future steps.

2.0 BULL KELP

Bull kelp is found in the Pacific Ocean along the Coast of North America, spanning from Unmak Island, Alaska to Point Conception, California (Springer, Hays, Carr & Mackey, 2007). *N. luetkeana* is a brown macroalgae that grows on bedrock and boulders in nearshore environments, 3 to 20 metres deep (Springer et al., 2007). Bull kelp spores germinate once they have settled in the rocky intertidal zone; when developing, they grow vertically, towards the ocean surface (Springer et al., 2007). The structure of bull kelp ensures that they are able to reach the surface, where there is maximum light; at the end of the stipe, which grows from the bedrock to the surface, there is a gas-filled float, known as a pneumatocyst, that keeps the kelp afloat (refer to Figure 1). (Springer et al., 2007). From the pneumatocyst, the alga blades grow; an adult bull kelp can cultivate 30 to 60 blades, each plant attempting to maximize their ability to photosynthesize (Springer et al., 2007). Once they have reached maturity, *sori* (spores) grow in patches on the fronds; when fully developed, the patches abscise and drop to the ocean floor where they will ultimately germinate and reproduce the bull kelp in the next growing season (Springer et al., 2007).

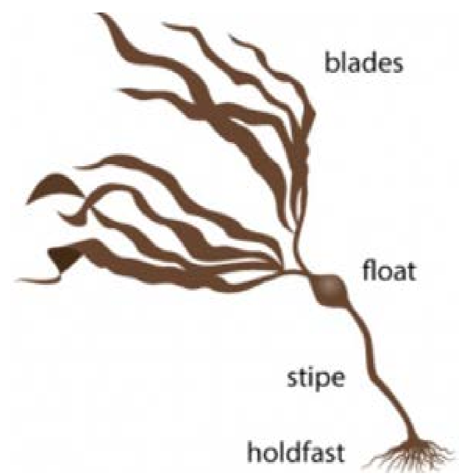

Figure 1. Bull kelp morphology (Inouye, n.d.).

2.1 Local History

The cause of the decline of bull kelp in the Georgia Strait is unknown, but it is thought to be attributed to changing environmental conditions, climate change, and the commercial harvesting of bull kelp (Oregon Coast Aquarium, 2017). The first commercial harvesting of bull kelp in the Strait of Georgia occurred in 1949, by Canada Kelp Co. Ltd., but due to finances, did not succeed (Springer et al., 2007). The first prosperous bull kelp commercial harvesting company, the Sidney Seaweed Products, harvested from 1965 to 1974 with economic gain (Springer et al., 2007). Currently, commercial harvesting of bull kelp is quite restricted and has a strict protocol, ensuring that 20% or less of the kelp bed biomass is not removed, the pneumatocyst and stipe are not harvested, and the blades must be cut more than 20 centimeters from the pneumatocyst to ensure that no damage to the alga occurs (Springer et al., 2007). Commercial harvesting of bull kelp requires a license that can be purchased and the province reserves the right to deny one to anyone that applies if they feel they are not capable of correctly harvesting the kelp (Springer et al., 2007). Unfortunately, there are no regulations for non-commercial harvesters; therefore, there is no enforcement and it is not clear what amount of bull kelp are being harvested, nor the effect this may be having on the bull kelp biomass in the Strait of Georgia (Springer et al., 2007). In addition to the unregulated non-commercial harvesting of bull kelp, the bull kelp is having to overcome the changing ocean environment (World Wide Fund for Nature (WWF), 2017). With climate change intensifying, there are more changes occurring in the ocean than ever before (WWF, 2017); bull kelp have oceanic conditions they prefer, and when those change there is potential for the bull kelp to diminish, like they have been, noticeably, for the past 30 or more years (Lamb, Gibbs & Gibbs, 2011). Bull kelp are vulnerable to a number of limiting factors, which are subject to change with the changing climate and the correspondingly changing environment (Springer et al., 2007).

There have been multiple research groups monitoring and studying bull kelp around Vancouver Island, primarily along the West Coast and in the San Juan Islands at the South end of Vancouver Island. Unfortunately, little work has been done in the Strait of Georgia and for that reason there is a significant lack of data regarding bull kelp in that region. However, it has been noted by many First Nations groups, fishermen and other groups that have used the Strait of Georgia over the last few decades that there has been a significant decline in bull kelp, especially in the last thirty years (Lamb et al., 2011). The majority of work that has been done regarding bull kelp within the Strait of Georgia involves mapping bull kelp, as well as some restoration efforts because of the noticeable decline in densities over the last thirty years (Government of British Columbia, n.d.; Heath, 2016). Although declining, bull kelp can be found in smaller densities continuously at the northern and southern entrances to the Georgia Strait, as well as in tidal passages with a fast current (Lamb et al., 2011). However, the regions that fall between the northern and southern entrances, with the exception of the high energy tidal passages, have been found to have minimal bull kelp in them (Lamb et al., 2011). There have not been any noticeable shifts in the ecosystem diversity, therefore the reason for the lack of kelp in the central Strait of Georgia is not clear (Lamb et al., 2011).

2.2 Ecological Importance

With each plants ability to cover significant area, multiple individuals form what is referred to as a kelp bed or forest. The density of bull kelp beds has the ability to slow the nearshore currents down, which has multiple beneficial effects (Springer et al., 2007). By slowing the current down, the movement of phyto- and zooplankton is also relaxed, which makes the bull kelp bed prime habitat for many organisms, such as salmon (Springer et al., 2007). Bull kelp beds have been found to boost biodiversity in nearshore habitats because of the protection and resources that they provide to their inhabitants (Steneck, Graham, Bourque, Corbett & Erlandson, 2002). Along with biotic interactions that bull kelp beds offer, they also provide the coast protection from storm surges and wave action. *N. luetkeana* slows the movement of the water and buffers the shoreline from the force of incoming waves (Springer et al., 2007). Another benefit of kelp forests are the climate change mitigation effects that they have. Kelp forests are carbon sinks, using carbon dioxide in photosynthesis and storing carbon in their blades and stipe (Krause-Jensen, 2016).

Since bull kelp has a multitude of benefits, through time it has become a significant resource with a substantial socioeconomic value to humans (Springer et al., 2007). Bull kelp forests maintain a high biodiversity of species which attracts various human activities, including SCUBA diving, kayaking, bird watching, as well as, commercial and recreational fishing (Springer et al., 2007). It has beneficial nutrients, which makes it an important resource; bull kelp has been collected throughout history in British Columbia, starting with the First Nations, as a food and pharmaceutical resource (First Nations Health Council (FNHC), n.d.).

The direct extraction of bull kelp from the nearshore environment can result in the reversal of all of the previously listed benefits (Springer et al., 2007). Overtime, since the start of bull kelp harvesting and initial changes in the climate, there has been a clear decline in the biomass of bull kelp that is present in the Strait of Georgia (Lamb et al., 2011).

2.3 Bull Kelp Vulnerability

Recent studies have shown that bull kelp recruitment is sensitive to temperature (Schiltroth, Bisgrove, & Heath, 2018). Bull kelp plants are susceptible to disintegration and ultimately death when water temperatures remain above 18°C for an extended period of time (Macrae, 2018). Additionally, the spores are 50% less likely to drop and germinate when the temperature is greater than 17°C and are 100% likely to die at 20°C or greater (Schiltroth, Bisgrove, & Heath, 2018).

In addition to temperature vulnerabilities, bull kelp have been indirectly impacted by the sea star wasting disease that the Pacific Northwest from California, north to Alaska experienced, starting in 2013 (Schultz, Cloutier, & Côté, 2016). Early September 2013, British Columbia began to feel the effects of the sea star wasting disease, as sunflower star (*Pycnopodia helianthoides*) populations began to plummet (Schultz, Cloutier, & Côté, 2016). Sunflower stars are the major predator of green sea urchins (*Strongylocentrotus droebachiensis*), which are a major driving species in changes in the local community; as green sea urchin populations increase, bull kelp populations decrease as a result of overgrazing (Schultz, Cloutier, & Côté, 2016). Therefore, with no major population of predators anymore, the sea urchin population exploded in the Strait of Georgia area, having a direct influence on the extent of bull kelp forests (Schultz, Cloutier, & Côté, 2016).

Nearshore regions are very dynamic environments, as they are exposed to both natural processes and anthropogenic pressures. Therefore, it is possible that there are other influences that are impacting bull kelp populations, but at this point these two aspects seem to be the driving factors with regards to bull kelp declines.

2.3.1 Abiotic Limiting Factors

There are multiple abiotic factors that affect the biomass and distribution of bull kelp in the nearshore environment, including light, temperature, salinity, pH, nutrients, sedimentation, and current (Dayton, 1985). The most important limiting physical factor affecting bull kelp success is light availability (Springer et al., 2007). Research has found that the northern range of bull kelp, along the Alaskan coast, is constrained by light availability; the length of daylight varies significantly in higher latitudes, with minimal light in the late fall and winter making it difficult for bull kelp to establish (Steneck et al., 2002). Without light, *N. leutkeana* is unable to photosynthesize, which is the source of all of its energy for growth to the surface (Dayton, 1985). Typically, bull kelp grow as tall as the water column is deep; on average, the kelp grows between 10 and 17 metres tall (Springer et al., 2007). Bull kelp has the potential to grow approximately six centimetres a day, allowing the bull kelp forest to replenish itself rapidly when the canopy is reduced due to a disturbance (Springer et al., 2017). Although, when light is limited, bull kelp growth is diminished until light becomes available (Springer et al., 2007).

The range of bull kelp along the Pacific Coast of North America is constrained by oceanic temperatures (Springer et al., 2007). Research has shown that *N. leutkeana* sporophyte and gametophyte reproduction occurs best when the ocean is 3°C to 17°C (Springer et al., 2007). Outside of the preferred temperature range, sporophytes and gametophytes had less reproductive success, therefore fewer are able to establish themselves on the rocky substrate (National Marine Sanctuaries (NMS), 2017b). Further studies have uncovered that thermal pollution, increased oceanic temperatures due to anthropogenic sources, have diminishing effects on the bull kelp sporophytes and gametophytes (Springer et al., 2007). Not only were there negative effects on the juvenile bull kelp, but the study found that when *N. leutkeana* was exposed to waters above 18°C for extended periods of time, it proved to be lethal (Springer et al., 2007). The central Strait of Georgia bull kelp has been exposed to marine temperatures greater than 16°C for extended periods of time; the same locations that have had this temperature spike have been experiencing a decline in the presence of bull kelp (Heath, 2016).

Bull kelp grows best in clear water; since growth is by photosynthesis, light is required at all stages of life from spore to adult (NMS, 2017b). When light levels are decreased, photosynthesis decreases and there is potential for the individual plant to not reach the surface and maximize its photosynthesis (NMS, 2017b). Sedimentation causes a significant decline in light penetration (Springer et al., 2007). Sedimentation can occur from particulate runoff from land or from marine activities, such as dredging, that stir up the bottom sediment enough that it remains suspended in the water column (Springer et al., 2007). Additionally, storm surges can have the same effect as dredging, where the bottom is significantly disturbed (Springer et al., 2007). In addition to diminishing amounts of light reaching the bottom, sedimentation hinders spores and reproductive stages from growing and flourishing (Carney, Waaland, Klinger & Ewing, 2005).

In the nearshore environments, the availability of nutrients varies temporally and spatially for bull kelp, which influences productivity levels, significantly (Carney et al., 2005). Bull kelp growth depends on carbon, nitrogen, phosphorus and many other micronutrients to grow; if there are limited concentrations of these nutrients available, bull kelp growth is limited (Springer et al., 2007). Typically, late winter and early spring is when nitrogen concentrations are highest, due to the influx of nutrients from terrestrial runoff; during this time is when bull kelp first begin to grow. By summer, photosynthesis rates peak because that is when the carbon to nitrogen ratio is the highest (Springer et al., 2007). Generally, after the peak, the nitrogen levels decline and photosynthesis follows suit. Although bull kelp requires nutrients, bull kelp experience significant consequences when concentrations are too high (Springer et al., 2007). Excessive concentrations of nutrients can be caused by runoff from terrestrial agricultural and urban landscapes, ultimately disposed of into the ocean with little or no treatment. When excessive nutrients are available, phytoplankton blooms may occur, which reduce light's ability to penetrate the water to depth, impeding photosynthesis and growth of bull kelp (Springer et al., 2007).

Bull kelp have the ability to adjust their growth patterns depending on the water current; when the water is quicker moving, the blades are flatter and strap-like, whereas when the water is slower, the blades have a wavy shape and are wider (Koehl & Alberte, 1988). The current determines the kelp physiology as well as growth rate (Koehl & Alberte, 1988). Bull kelp is found primarily in locations that experience upwelling, which involves wind or current pushing surface water offshore while cold, nutrient-rich water from depth flows into the nearshore environment to fill the area of displaced water (Springer et al., 2007). Bull kelp growth is subsequently reduced when upwelling slows because the cool water and nutrient concentration diminishes (Springer et al., 2007). Along with current, wave action also has an impact on bull kelp (Denny, Gaylord & Cowen, 1997). When waves are very strong, they have the ability to rip bull kelp off of the substrate, which is very harmful to the population because when bull kelp detaches, it cannot be reattached (Denny et al., 1997). Therefore, storm surges and big waves have the ability to remove entire bull kelp beds (Denny et al., 1997).

2.3.2 Biotic Limiting Factors

In addition to the abiotic limiting factors that affect bull kelp growth, there are many biotic limiting factors, that alone and in combination with the abiotic factors can have a significant impact on bull kelp. Some of the biotic limiting factors are predation, competition, epiphytes, and disease (Springer et al., 2007).

Although bull kelp has the ability to grow incredibly fast, they have many predators that reduce their chances of doing so. In the Strait of Georgia, bull kelp has numerous invertebrates that graze upon them, including red and purple sea urchins (*Strongylocentrotrus franciscanus* and *S. purpuratus*), snails (*Tegula* spp. and *Callistoma* spp.), many limpets species, including the shield limpet (*Collisella pelta*), red abalone (*Haliotis rufescens*) and crustaceans (Springer et al., 2007). These predators are capable of weakening the bull kelp, by grazing on their stipe and removing their hold from the rocky substrate (Springer et al., 2007). Once the bull kelp is removed from the rocks, they are unable to re-attach, meaning that they are no longer continuing their vertical growth, but they will continue to photosynthesize and can act as a moveable, floating refuge for many fish species (Fulton-Bennett, n.d.). Grazing is a significant driver of bull kelp abundance and density; survival and reproduction of bull kelp depends on their spore's ability to germinate and grow, which is not possible if there is an excessive amount of grazing (Springer et al., 2007).

Bull kelp is an opportunistic species and because of their quick growing abilities they are typically found at sites that were recently disturbed or in early successional stages (Watson, 2014). When there is minimal herbivory and few other macroalga species to compete with, bull kelp thrives and can form a dense forest (Springer et al., 2007). However, if bull kelp undergoes high herbivory or a disturbance, their once high density may be outcompeted by other species of alga (Edwards & Foster, 2017). Even when bull kelp is the first to arrive and flourish, when there are no disturbances or predation it is typical that they eventually become outcompeted by perennial species, such as giant kelp (*Macrocystis pyrifera*) (Edwards & Foster, 2017). Adverse effects also occur when there is herbivory on bull kelp; by depleting its density, other macroalga species are able to take over more easily (Edwards & Foster, 2017). In areas where giant and bull kelp are able to coexist, the bull kelp is found in the regions that are more exposed and the giant kelp densities are low (Springer et al., 2007). Ultimately, disturbance events can have either a positive or a negative effect on a bull kelp forests, depending on the timing of the event.

Epiphytic algae are another biotic limiting factor on bull kelp beds. Epiphytic alga are species of alga that live on other algal plants, such as *N. leutkeana*; these species do not have any holdfasts to the intertidal zone, but rather to the algae it's attached to (Government of Western Australia (GWA), n.d.). Typically, epiphytes do not have an impact on their host algae unless there are excess nutrients available, which source a bloom; the bloom is able to coat the alga and reduces the algae's photosynthetic abilities by shading the blades of bull kelp from absorbing light (GWA, n.d.). There are over 50 species of epiphytic algae and invertebrates that use bull kelp as their host (Springer et al., 2007). An epiphyte that is known to grow on the stipe of bull kelp is Thallus (*Porphyra nereocystis*); it is a reddish alga, with a strap-shaped blade, which covers the bull kelp stipe near the surface, reducing bull kelp's photosynthetic abilities (Seaweeds of Alaska, n.d.). The surface area that epiphytic species coat continuously increases throughout the summer, impacting them through their principal growing season (Springer et al., 2007). Additionally, if there is significant epiphytic cover, the weight of the epiphytic algae may overwhelm the pneumatocyst, resulting in the bull kelp sinking, causing a reduction in direct sunlight as well as lowering the blades to a height in the water column where they are more vulnerable to herbivory (Springer et al., 2007).

Finally, bull kelp is vulnerable to disease, which can leave the algae suseptable to further damage and breakage (NMS, 2017a). Currently, there is only one parasitic alga that is known to infect bull kelp, which are brown alga species (*Streblonema* sp.); they can cause a variety of damages (Springer et al., 2007). *Streblonema* sp. are able to cause "galls and extended rugose areas" to occur on the stipe, as a result these damaged and deformed areas of the stipe cause the stipe to weaken and eventually break (Springer et al., 2007). Parasitic algae have the potential to destroy entire bull kelp beds by slowly damaging them enough that the environment will completely destroy the plant (NMS, 2017a).

2.3.3 Anthropogenic Factors That Limit Bull Kelp

Since bull kelp grows in nearshore environment, it is consequently very close to humans and the damaging impacts they cause to the environment through a variety of factors, such as direct extraction, modification of ecosystems, pollution and climate change (Springer et al., 2007). Bull kelp suffers from direct extraction because it is a species that has multiple beneficial uses to humans, including human consumption in a variety of foods and drinks, its use in agriculture, to feed livestock and marine aquaculture, as well as its used for fertilizer, biofuel, and cosmetics (TasKelp, 2017; Koukel & Rodgers, 2015). Although bull kelp has so many benefits to humans, if harvested incorrectly the extraction of it is detrimental to entire kelp forests (Springer et al., 2007). In total, the biomass of bull kelp that is directly extracted is minimal compared to other kelp species, but the extraction of it is limited to the upper two metres of the forest because it is principally collected from a boat by hand (Springer et al., 2007). By removing the upper two metres of each of the plants, the pneumatocyst, which keeps the kelp afloat, is removed causing the rest of the plant to sink; therefore the plant is no longer able to grow vertically in the water column, to the surface, nor is it able to photosynthesize to continue growth at all (Roland, 1985). Additionally, the spores that are released each year, which reseed the kelp beds, are on the blades of the plant; if these blades are collected prior to reproduction and the release of the spores, the following generations of bull kelp may not occur (Roland, 1985). Ultimately, if humans are going to continue to harvest bull kelp, sustainable methods need to be considered.

Another anthropogenic factor is the modification of ecosystems, which can occur as a result of non-native, or invasive species being introduced to the nearshore habitat either by a vessel bringing them in on the hull or in their ballast water that is released into their destination's harbour (Madelung, 2010). Nearshore environments are very vulnerable to invasive species, as they can significantly change the ecosystem dynamics. Invasive species are those that typically thrive because in their new habitat they do not have any natural predators; therefore, they are able to outcompete species that do have natural predators and other competitors (Madelung, 2010). There is potential for invasive species to disrupt native species ecosystem interactions and dynamics (Springer et al., 2007). Additionally, modifications of the nearshore ecosystem can occur as a result of humans changing native species' populations, which have the potential to critically impact the bull kelp densities (Springer et al., 2007). For example, when sea otters were extirpated from the marine environment surrounding Vancouver Island, the bull kelp forest's density declined greatly (Watson, 1993). Sea urchins are one of the primary consumers of bull kelp and one of the principal prey species for sea otters; therefore, when sea otters were removed, the trophic cascade ensued, allowing sea urchin populations to inflate, subsequently removing the dense bull kelp beds that once were (Watson, 1993). From this example, it is clear that humans need to be cautious of their actions and alter species populations as minimally as possible to ensure that ecosystem dynamics are not adversely affected.

As stated, bull kelp beds are in the nearshore environment, which is adjacent to the terrestrial environment that humans have substantially polluted. Pollution occurs in the marine environment in various forms, including wastewater, thermal discharge, and marine pollution (Springer et al., 2007). Wastewater is any sources of water that has had the quality of it compromised due to anthropogenic actions; wastewater comes from urban and agricultural properties, it contains various nutrients and toxins that can be harmful to the nearshore environment (UN Environment, 2015). Wastewater includes any water that was used in domestic households, as well as untreated runoff from urban streets that flows directly into the aquatic and marine waterways (UN Environment, 2015). If the wastewater that is released is nutrient rich, when it reaches marine waterways it can result in significant algal growth and blooms; dependent on species of algae, the bloom could release harmful toxins, which could impact species in the nearshore environment (UN Environment, 2015). In addition to toxins, algal blooms shade bull kelp in the nearshore, reducing photosynthesis potential (UN Environment, 2015). Another form of pollution is thermal discharge; it is heated water that is released into aquatic and marine waterways from coastal power plants, factories, mills, and other industries that use heated water (Murugesan, Rameshwari & Sukumaran, 2002). Typically, the effluents are eight to ten degrees Celsius warmer than the marine water (Murugesan et al., 2002); this temperature difference would negatively impact bull kelp because it has difficulty surviving in water that is warmer than 18◦C (Heath, 2016). Finally, the third common form of pollution in the marine environment is referred to as marine pollution, which includes gasoline, oil, garbage, sewage, and other harmful substances, from marine traffic (International Maritime Organization (IMO), 2017). Although pollution from ships do have negative impacts on the marine waters, there has been significant effort to reduce the impact of ships and do the most we can to prevent harmful accidents from occurring; efforts include the International Maritime Organization signing 51 treaties to regulate international shipping, 21 of which are related directly to the environment (IMO, 2017). Pollution of the marine environment, specifically the nearshore, is an important issue that humans need to make a conscious effort to prevent from happening.

Multiple factors associated with anthropogenically caused climate change have impacts on the bull kelp densities in the Pacific Northwest, including changes in upwelling processes, as well as increasingly larger and unpredictable storm events. Firstly, climate change has altered the upwelling processes that were once very predictable because of our understanding of atmospheric conditions (Springer et al., 2007). Bull kelp growth depends on the cold, nutrient-rich upwelling waters, which without they will struggle to exist (Springer et al., 2007). Unfortunately, with changes to atmospheric conditions (i.e., timing, location, and intensity of coastal winds) upwelling may become less common or change in intensity, which could make the existence of bull kelp in the Pacific Northwest insurmountable (Harley et al., 2006). If there are changes to the cool California current that comes from Alaska, along the coast of British Columbia, past Vancouver Island, there is potential for changes in the bull kelp densities even further than what has already occurred (Harley et al., 2006).

The other limiting factor, as a result of anthropogenic climate change, is the larger, unpredictable storm events associated with El Nino Southern Oscillation (ENSO) that have been occurring (Springer et al., 2007). The variables associated with ENSO, including frequency, duration, and strength of ENSO, have changed in the past decade; there has been an increase in each of the variables resulting in larger, longer-lasting, and more frequent storm events occurring (Springer et al., 2007). The bull kelp in the regions that these storm events occur in are negatively impacted. The intense winds and currents that result from the storms cause breakage of bull kelp, the holdfast does not remain attached to the rock or the stipe breaks and the bull kelp is left afloat, no longer contributing to benefits that are associated with the bull kelp bed (NMS, 2017a). With larger and stronger storms, there is potential for bull kelp forests to be destroyed in their entirety, which would result in these coastal regions losing biodiversity, coastal protection, and a carbon sink (Lamb et al., 2011).

3.0 PROJECT OBJECTIVES

The primary objective of this project is to re-establish populations of bull kelp that were once thriving in the Strait of Georgia by planting pre-seeded kelp lines. Additionally, we wanted to monitor their growth, observe their health throughout the season, as well as identify if there were notable differences in biodiversity or the species' types that were using the area when there was and was not bull kelp present.

4.0 METHODS

The sites chosen for the bull kelp enhancement plots, Dodd Narrows and the Winchelsea Islands, were selected based on historical knowledge that was collected when speaking with local SCUBA divers and fisherman that had been active in the Central Strait of Georgia for the last 30 years. Additionally, site visits were conducted prior to this project, in the summer of 2017, to determine if there was any bull kelp in the vicinity; there was a small bed found just south of the Dodd Narrows site, however none was found around the Winchelsea Islands.

4.1 First Planting Season: 2018

The planting of the seeded bull kelp lines was done so following the methods that Project Watershed established in 2014, which were used at the enhancement plots they constructed off of Hornby Island (Heath & Chambers, 2014). Each rope that bull kelp was to grow on required a set of two concrete anchors with 19mm diameter polysteel floating rope strung between them. Prior to tying the rope off to the second concrete anchor, two spools of pre-seeded kelp line, that are wrapped around 2 inch PVC pipe, were tied onto the rope. The first concrete anchor with all the rope and pre-seeded line strung onto it is then slowly lowered to the ocean floor; as the anchor is dropped, the pre-seeded kelp slides off of the PVC pipe and naturally wraps around the floating rope. Once the anchor has reached the ocean floor and the pre-seeded kelp line is fully extended along the rope, the kelp line is tied off and the rope is cut and tied on to the second anchor. The second anchor is then pulled taught and lowered to the ocean floor. Following the drop of the kelp line, the SCUBA divers dove down to ensure that the kelp line was running parallel to the shoreline, as well as settled on even ground, ensuring that it was floating above the ocean floor and not resting on it. The 2018 planting was completed on March 4 and 5, 2018.

Figure 2. Bull kelp pre-seeded lines spooled around PVC pipe, prior to stringing it onto polysteel floating rope (MABRRI, 2019).

In 2018, the bull kelp planting occurred at a later date than what would have been preferable as a result to the timing of funding announcements and MABRRI's ability to gather all of the supplies in order to undertake the field work. It is anticipated that the later timing window, in addition to the algae bloom that occurred directly after the installation, did not provide the kelp enough time to properly establish itself as we were not seeing much growth. Therefore, we adapted to this and in order to determine if the bull kelp would actually persist at each of the sites, the team gathered 24 individual bull kelp plants that had floated away from their beds from around Mudge Island, De Coursey Island, and Gabriola Island and

Figure 3. 'Method A' used in transplanting bull kelp (MABRRI, 2018).

Figure 4. 'Method B' used in transplanting bull kelp (MABRRI, 2018).

'transplanted' them at our sites. In order to attach each individual bull kelp to the existing kelp line at each site, two different methods were used. Both methods were prepared at surface, with the actual transplant undertaken by the SCUBA divers. Each individual plant was measured prior to transplant, given a code, which was attached to it (i.e. D1, D2, W1, W2, etc.), and the method used to attach it to the floating rope was recorded for each corresponding individual. The first method, referred to as 'Method A' used a piece of nylon cord, with a loop at either end of it. One end of the cord was looped around the stipe of the bull kelp, above the holdfast, while the other was attached to the floating rope with a cable tie. The second method, referred to as 'Method B' had the holdfast directly fastened to the floating rope using veterinary tape and a cable tie overtop of the veterinary tape. In total, 12 bull kelp plants were transplanted to each of the sites.

Regular monitoring of the sites occurred, visiting monthly in most months and bi-weekly during the anticipated peak-growing season (June, July, and August). During each site visit, video surveys were conducted, as well as measurements taken. A swim through of the line was completed, which involved the SCUBA divers swimming along the line and recording what the bull kelp looked like, as well as aid us in the identification of any species that were using the bull kelp as a habitat. Additionally, a one metre squared quadrat was taken down to the ocean floor with the SCUBA divers to be placed at three semi-permanent locations, each marked with two bricks that had been glued together to form an "L". The quadrat was placed in the same position each time, by wedging the bottom left-hand corner of the quadrat in the "L" of the bricks, and the diver

Figure 5. Bull kelp sori (spore) patches (MABRRI, 2018).

would take an up-close video recording of the one metre squared area. Further, the divers would use a measuring tape to measure the length of each of the transplanted bull kelp plants, recording their observations on underwater slates. The divers would record when bull kelp plants had been lost, most likely as a result of strong currents or grazing. Toward the end of the growing season, the divers would take a close look at the remaining individuals and note if there was or was not *sori* (spore) patches present on the fronds and whether or not there was evidence of the patches dropping.

During each visit, the boat attendants would collect water profile data, using a YSI Pro DSS sonde to determine the temperature, dissolved oxygen, salinity, conductivity, pH, and turbidity at one metre increments from the surface to the bottom. These measurements were taken at an "inner" site, approximately 7m depth and near the enhancement plot, and an "outer" site, approximately 16m depth.

Finally, there were two methods of monitoring that were continuous for a period of time at each of the bull kelp sites. Data loggers were installed at each of the sites, on the bull kelp line, and at an "outer" site in deeper water (~18m), each data logger recording the temperature and light availability every 30 minutes. Additionally, an underwater time lapse camera was installed at the site, it would take a photo every hour from 07:00 to 18:00, not recording any photos during the night as it depended on natural light for photos. The photos were analyzed in order to determine any species that may be using the bull kelp as habitat, but could be potentially scared away when the SCUBA divers were present. The camera was left at each site for one month during July and August.

4.2 Second Planting Season: 2019

The exact same methods were used in the 2019-growing season to deploy the bull kelp seeded lines. The bull kelp planting occurred on January 13, 2019, providing it with a greater window to establish and grow than those planted in 2018.

There were two minor differences between the 2018 and 2019 planting events: there were three bull kelp seeded lines, each approximately 30m long, strung along a new piece of floating rope that was attached at either end to two concrete blocks, instead of two pre-seeded bull kelp seeded lines, and additional concrete anchors were dropped in anticipation of greater growth rates. The added weight was to ensure that the bull kelp plots would not be lost, especially in the Dodd Narrows site, as there is a greater current there.

The monitoring activities completed in the 2019 growing season were the same as those completed in the 2018 season, including: swim through video surveys, quadrat video surveys, collecting water profiles, temperature and light availability data loggers, identification of *sori* presence, and underwater time lapse cameras. One minor adjustment to the monitoring was with the measuring of the bull kelp height. Although the methods for recording the data was the same, the method to determine which plants would be monitored was different from the 2018 growing season. In 2018, there was a set 12 plants that would be measured, as they were the ones that were transplanted. Alternatively, in 2019, as there was significant bull kelp growth, it was decided that kelp growth would be selected at random; one individual every 5m along the floating rope was marked with a cable tie to ensure that identification of the individual would be made possible upon revisiting.

5.0 INITIAL RESULTS

Each year that we conducted the work there was differing results, likely as a result of the different methods that were undertaken. However, the following are the initial results that were found:

5.1 Swim Through Surveys

5.1.1 Dodd Narrow Site

At the Dodd Narrows site, no fish species were observed during the video and diver surveys at the time of the line deployment and when no kelp was present. However, as the kelp grew, more fish species were observed at the site. Although species of perch and herring were observed during diver and video surveys once kelp appeared, overall fish biomass over time appeared to be less at this site in comparison to the Winchelsea Islands site.

5.1.2 Winchelsea Island Site

At the time of deployment when no kelp was present, no species of fish were observed during video and diver surveys of the kelp lines. As bull kelp began to grow on the lines, juvenile rockfish were observed swimming around the kelp. Rockfish abundance continued to increase in numbers at this site as the kelp biomass accumulated. Similarly, species of perch increased in abundance with an increase in kelp biomass. Once the kelp had reached a mean height of approximately three meters, schools of herring (>50 individuals) were observed swimming around the kelp. Schools of herring also appeared more frequently as the kelp continued to grow.

5.2 Quadrat Surveys

5.2.1 Dodd Narrow Site

Species observed within the quadrats, as well as their densities, appeared to remain consistent throughout the course of this study at both sites. Therefore, no apparent change in biodiversity was observed in the quadrat video surveys before and after kelp growth. Common species of algae that were observed at the Dodd Narrow site were Turkish Towel (*Chondracanthus exasperatus*) and sugar kelp (*Laminaria saccharina*). Common species of invertebrates observed at the Dodd Narrows site were Ochre sea stars (*Pisaster ochraceus*), leather sea stars (*Dermasterias imbricata*), and giant California sea cucumbers (*Parastichopus californicus*). No fish species were observed in Dodd Narrows quadrats during video surveys.

5.2.2 Winchelsea Islands Site

Species observed within the quadrats, as well as their densities, appeared to remain consistent throughout the course of this study at both sites. Therefore, no apparent change in biodiversity was observed in the quadrat video surveys before and after kelp growth. Common species of algae that were observed at the Winchelsea Islands site were rock weed (*Fucus vesiculosus*) and sea lettuce (*Ulva lactuca*). Common species of invertebrates observed at the Winchelsea Islands site were purple sea urchin (*Strongylocentrotus purpuratus*), giant California sea cucumber, and frilled dog whelk (*Nucella lamellosa*). Common species of fish that were observed at the Winchelsea Islands site were black eyed goby (*Rhinogobiops nicholsii*).

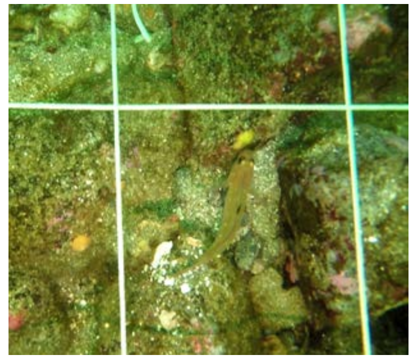

Figure 6. Black eyed goby in Winchelsea Island site's quadrat (MABRRI, 2019).

5.3 Kelp Measurements

Our visual surveys indicated a general increase in bull kelp biomass over the growing season at both sites. Most of the kelp at both sites were visible at the surface during low tide by the fifth site visit on August 10th, 2019 (day 76). However, no kelp was visible by the final dive on August 23rd 2019 (day 89) at the enhancement plot off Winchelsea Islands and only approximately half of the kelp appeared to be present at the surface at the Northumberland Channel site.

Over the course of the study, four of the six kelp measured at the enhancement plot off of the Winchelsea Islands were present up to day 76 (5th site visit) and grew an average of 0.7 cm/day, reaching a maximum average height of 99.8 cm. The remaining two kelp that were measured were only present up to day 55 (4th site visit) and grew an average of 0.7 cm/day, reaching a maximum average height of 86 cm. By the sixth survey, no kelp was observed on this line at this site.

At the enhancement plot in the Northumberland Channel, only four of the six bull kelp to be measured were still on the line at the time that stipe length measurements initially took place. Of those four kelp, two of them were still present during our final site visit; they grew an average of 9.8 cm/day and reached an average maximum height of 894.5 cm.

5.4 Water Profiles

In 2019, the sea surface temperature (SST) reached a maximum of 14.8°C and a minimum of 12.3°C across both the inner and outer sites at Winchelsea Islands throughout the summer months (Figure 1). The maximum difference in SST measurements between the inner and outer sites at Winchelsea on a given day was 0.2°C. The SST reached a maximum of 12.9°C and a minimum of 11.1 °C across the inner and outer sites at Dodd Narrows (Figure 1). The maximum difference in SST measurements between the inner and outer sites at Dodd Narrows on a given day was 0.1 °C.

SSTs in 2019 were consistently lower every month at the inner and outer sites of both the Winchelsea Islands and Dodd Narrows sites when compared to the 2018 summer months (Figure 1). In 2018, SST had a maximum value of 18.5°C and a minimum of 15.2°C at the Winchelsea Islands site. At both the inner and outer sites at Dodd Narrows, SST reached a maximum of 18.7°C and a minimum of 13.4°C.

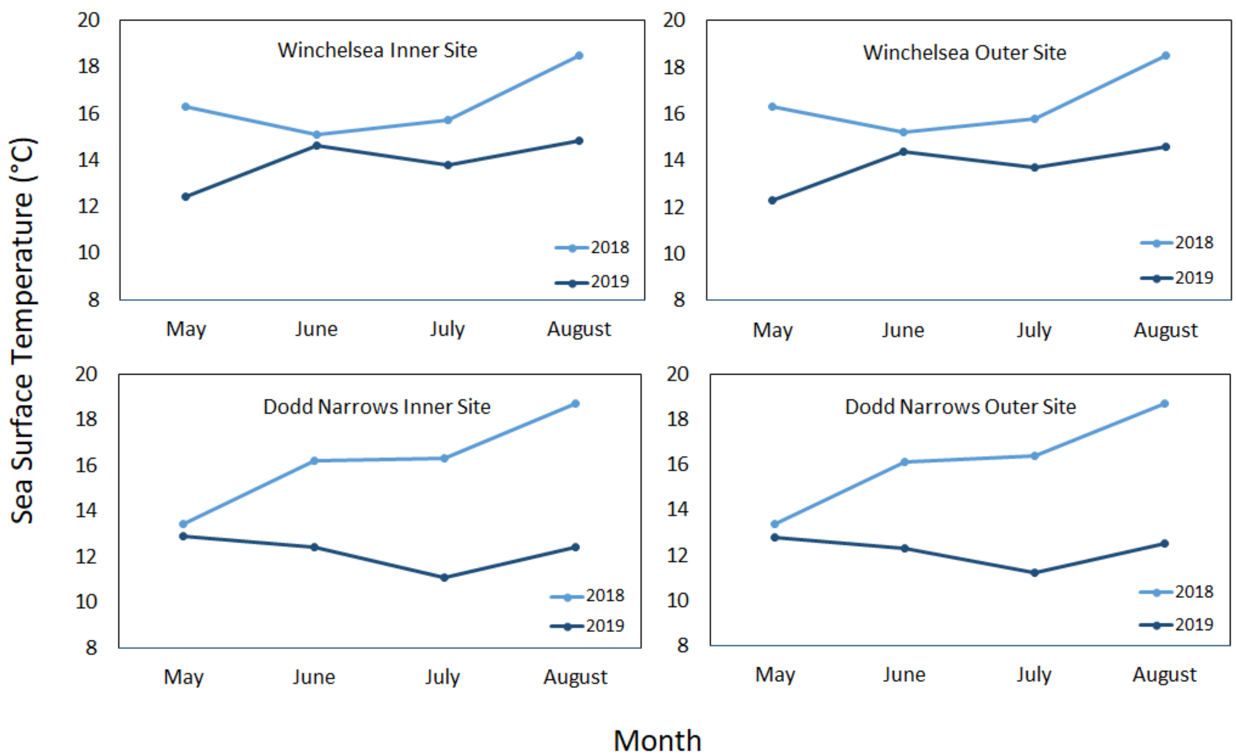

Figure 7. Sea surface temperatures (SST) (°C) of inner and outer sites at MABRRI's bull kelp enhancement plots located near the Winchelsea Islands and Dodd Narrows, British Columbia. SST measurements were taken at a depth of 1m with a YSI Pro DSS sonde.

5.5 Data Loggers

There were four HOBO data loggers installed at each sites, Dodd Narrows and the Winchelsea Islands. The data loggers recorded temperature (°C) and light availability (lux) every 30 minutes. The 'inner' data loggers at each site were strapped to the buoy line with cable ties, one at the bottom (0m) and one 6 metres up from the bottom (6m). The 'outer' data loggers were installed at each site using a concrete anchor, with a float tied onto it; two data loggers were installed on this anchor, one at the bottom (0m) and one 6 metres up from the bottom (6m). All the data was downloaded using HOBO Software and the daily averages were compiled for both the temperature and the light availability.

There are sources of error associated with the light availability readings from the data loggers as a result of invertebrate growth, blocking the sensor and reducing the readings, as well as strong currents moving the data logger on the line and pointing in a direction where it receives less light due to shadows.

5.5.1 Dodd Narrow's Temperature

The average daily temperature at both the inner and outer sites at Dodd Narrows were between 7°C and 18°C in 2018 and 6.5°C and 20°C in 2019. The inner 0m data logger saw two days with temperatures greater than 18°C in 2018, whereas in 2019, zero days recorded temperatures over 18°C. The inner 6m data logger had three days of temperatures greater than 18°C in 2018 and 5 days in 2019, with two of those days reaching temperatures higher than 20°C. The outer data loggers had the same results.

5.5.2 Winchelsea Island's Temperature

The average daily temperature at the Winchelsea Islands site was between 7°C and 19°C in 2018 and 7°C and 20°C in 2019. The inner 0m data logger recorded 12 days of temperatures greater than 18°C in 2018, with four of those days being warmer than 19°C. Alternatively, in 2019, the inner 0m data logger only had one day experience temperatures greater than 19°C. The inner 6m data logger saw temperatures greater than 18°C on 18 different days in 2018, with eight of those days being warmer than 19°C. In 2019, the inner 6m data logger had 13 days of temperatures greater than 18°C, with 7 of those days warmer than 19°C, and two of them being over 20°C. The outer data loggers reflected the same results.

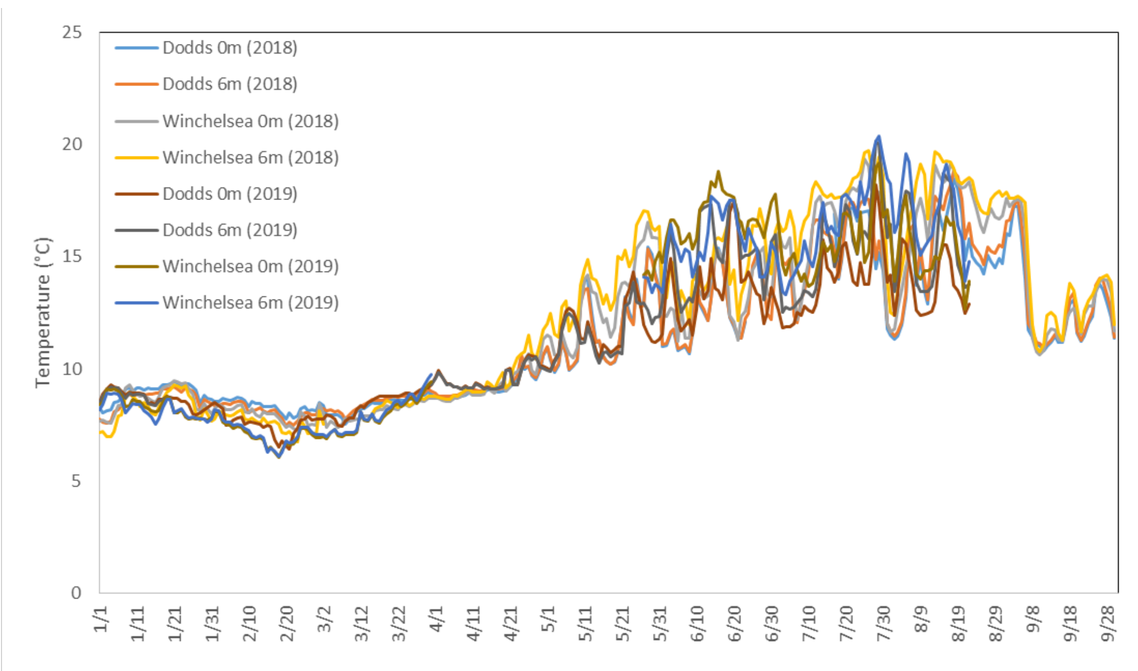

Figure 8. Average daily temperatures for Dodd Narrows and Winchelsea Islands 'inner' data loggers.

5.5.3 Dodd Narrow's Light Availability

The light availability at the Dodd Narrows site ranged from 0 lux to 2.1 lux (lux is a unit of illuminance, with one lux equal to one lumen per square metre). The peak light availability occurred in the summer each year. The inner 0m data logger peaked at 0.602 lux on May 17, 2018 and at 0.398 lux on June 18, 2019. The inner 6m data logger peaked at 0.609 lux on August 16, 2018 and 2.1 lux on June 7, 2019. The outer data loggers reflected what was observed in the inner data loggers.

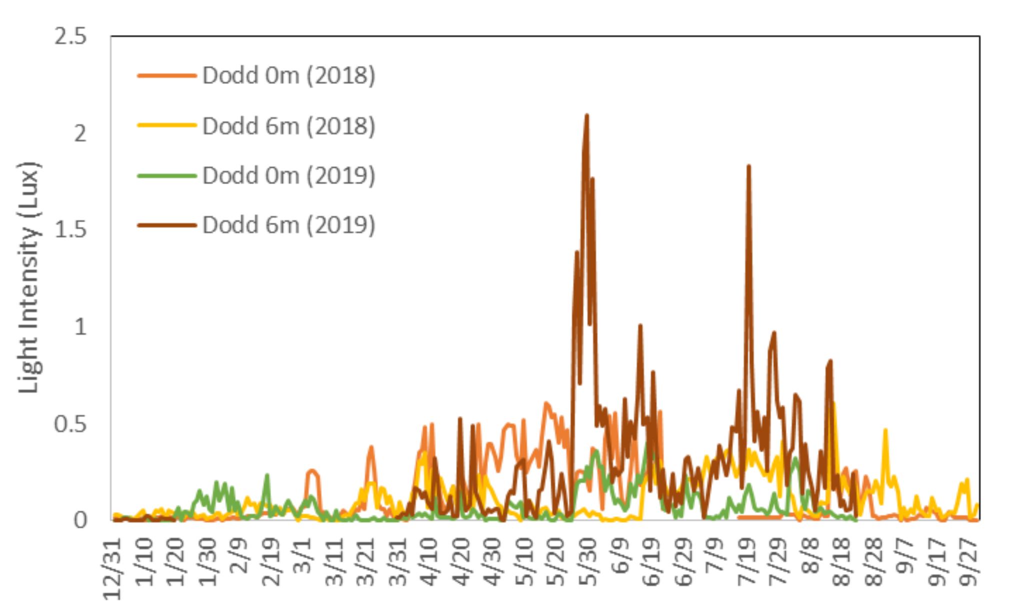

Figure 9. Dodd Narrows inner site temperature at 0m and 6m in 2018 and 2019.

5.5.4 Winchelsea Island's Light Availability

The light availability at the Dodd Narrows site ranged from 0 lux to 4.48 lux. The peak light availability occurred in the summer each year. The inner 0m data logger peaked at 1.48 lux on May 16, 2018 and at 3.53 lux on May 28, 2019. The inner 6m data logger peaked at 2.58 lux on May 16, 2018 and 2.44 lux on July 28, 2019. The inner 0m data logger malfunctioned, which is the reason there is a significant gap in the data that was collected (refer to Figure 10). The outer data loggers reflected what was observed in the inner data loggers.

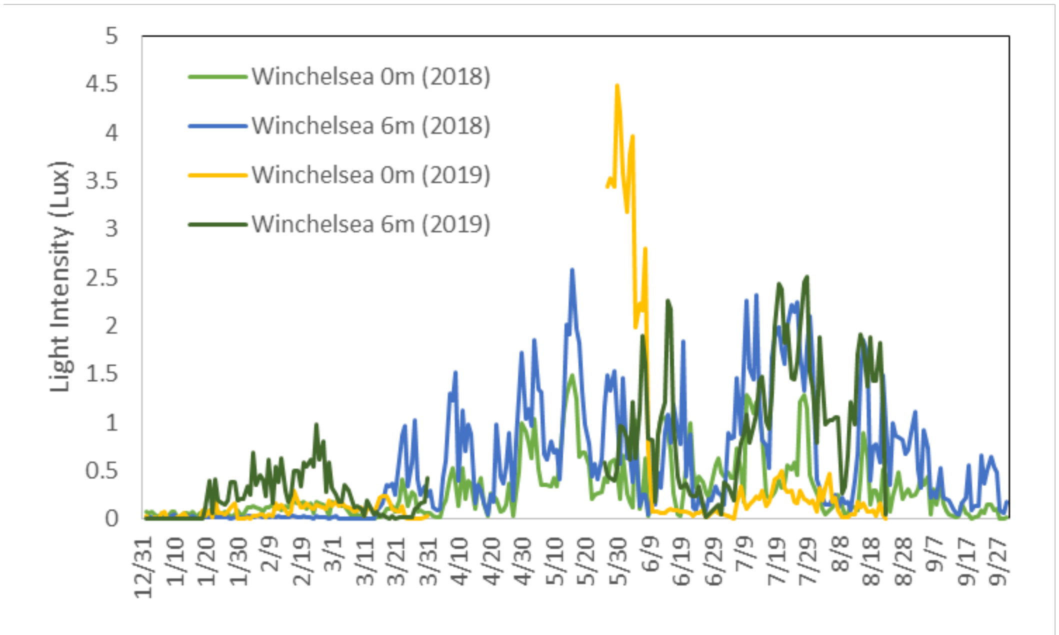

Figure 10. Dodd Narrows inner site temperature at 0m and 6m in 2018 and 2019.

5.6 Sori Check

The bull kelp that was transplanted at each site in 2018 did see *sori* (spore) development, however there was greater *sori* development in 2019 at the Dodd Narrow site than in 2018. We are unable to compare for the Winchelsea Islands site due to grazers consuming the bull kelp and not allowing it to fully mature in 2019.

6.0 DISCUSSION

Overall, the 2019 growing season was successful; an abundance of bull kelp grew at both sites. In 2018, the bull kelp on the lines did not grow from seed, they were established via a transplant (Shaw et al., 2018). It is unclear why the bull kelp seeded lines did not grow in 2018, however it may have been a result of a much later planting than that of 2019 (March versus January), in combination with variations in factors affecting bull kelp growth. Some considerations as to why there was greater success in bull kelp growth in 2019 versus 2018 could be the apparent variations in the sea surface temperature between the growing years. Sea surface temperatures in 2019 were consistently lower at both sites, which may have reduced thermal stress on the kelp and supported more successful growth. However, more years of data are required to confirm this hypothesis.

Through the video surveys of the kelp lines at both sites, the surrounding fish biodiversity near the enhancement plots appeared to have increased over time as the bull kelp increased in abundance and length. This suggests that the bull kelp at our sites were successful at providing habitat for organisms in the surrounding area. However, no apparent change in biodiversity was observed in the quadrat video surveys, suggesting that the kelp had no effect on surrounding local benthic invertebrates. Again, more years of data are required to make any conclusions.

Although during our final dive there were more bull kelp individuals being measured for stipe length at our site near Dodd Narrows, and those individuals had a higher growth rate over time, our video surveys indicated that there were more bull kelp individuals on the line at our site near Winchelsea Islands throughout the majority of the study. We recognize that our sample size of bull kelp individuals measured for stipe length was small and more individuals should be measured during the next growing season to better reflect those differences. This number was chosen due to the uncertainty of the bull kelp success rate using the pre-seeded line method and attaching the nylon cable ties before growth had begun.

Although this preliminary work shows the bull kelp will grow during the year, when planted, the big question now is what is occurring with the recruitment levels and why are they different from before. There is still a lot of work to be done in this field, including experimenting with different planting and recruitment methods. However, if this method ultimately proves to be successful with regards to recruitment ability, this method should continue to be used, as it is a cost-effective way to enhance bull kelp in the Strait of Georgia.

7.0 MABRRI NEXT STEPS

The team at MABRRI will be deploying new lines for a third growing season in 2020. We will continue to monitor bull kelp growth over time and aim to quantify its effects on the surrounding areas. In addition, more years of data are needed to observe if the planted bull kelp is able to replenish itself. By collecting more data, this will also help us understand site effects and determine the most suitable locations within the Strait of Georgia to implement these techniques and establish more bull kelp enhancement plots. Long term efforts to support reestablishing bull kelp through enhancement plots will require further funding and support. Expanding upon our existing network of plots will further increase habitat availability for a variety of organisms, while contributing to a better understanding of the results of this study.

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