Cedar Coast Field Station

Pilot Study: Canopy-Forming Kelp Monitoring in Clayoquot Sound 2018

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Figure 1- Sea otter in bull kelp. (Source: M. Bartlett)

Introduction

Forests sway under the ocean's surface in Clayoquot Sound. Clayoquot Sound is located within the traditional territories of the Central Region Nuu-chah-nulth First Nations, comprised of the Ahousaht, Hesquiaht, Tla-o-qui-aht, Toquaht, and Nuu-cluth-aht Nations (Nuu-chah-nulth Tribal Council, 2019). These subtidal forests, reaching up to 10 meters tall, are formed by canopy-forming brown algae, known most commonly as kelp. Kelp forests support and sustain a rich and dynamic assemblage of life, with a square kilometer of forest containing up to as many as 67,000 organisms (Byatt, 2001). As primary producers, the wellbeing of kelp, and seaweed in general, is extremely important in maintaining the overall health of marine ecosystems (Burt, et al., 2018; Duggins, et al., 1998; Wan Wagenen, 2015). Climate change is causing major shifts in marine environments (Ministry of Environment, 2016) and there is mounting pressure to document and monitor ocean ecosystems and marine biodiversity (Hillebrand et al., 2018). Recently, extreme decreases in kelp populations throughout the Pacific have been documented (Burt, et al., 2018; Catton et al., 2016). As an ecosystem indicator and engineer, kelp is extremely important to monitor. Cedar Coast Field Station (Cedar Coast) is currently undertaking several biodiversity monitoring projects, and we are in the preliminary stages of establishing a long-term kelp monitoring program in Clayoquot Sound.

Ecological Vulnerability of Kelp Forests

On the coast of British Columbia, two canopy-forming kelps exist, *Nereocystis luetkeana*, commonly known as bull kelp, and *Macrocystis integrifolia*, or giant kelp. Both of these species range from Alaska to California, growing independently and in mixed beds- two or more canopy-forming kelp species in one defined bed (Byatt, 2001). Canopy-forming kelp is highly sensitive and susceptible to a number of natural and anthropogenic impacts, and is often refered to as an indicator species. In particular, changes in sea surface temperatures (SST), salinity, climate cycles, nutrient availability through upwelling, extreme storm activity, pollution, development, and harvest can all impact kelp populations (Britton-Simmons et al., 2008; Sutherland, 1999; Pfister et al, 2017). Rising SST, from natural cycles such as El Niño events and larger scale climatic changes, especially threaten kelp forests (Arafeh-Dalmau, 2019). The interconnections and accumulative impacts of these various stressors are not fully understood and cannot be easily predicted, especially with more extreme and rapid shifts due to climate change (Reed, 2016; Hakai, March 2016).

Beginning in fall of 2013, an irregular marine heatwave, commonly known as "the Blob" hit the north Pacific in the Gulf of Alaska (Reed, 2016). For three subsequent years the Blob traveled south towards Mexico, having immense impacts on Pacific marine environments (Arafeh-Dalmau, 2019; Hakai, March 2016). The Hakai Institute (Hakai) connects the Blob with a 2015 toxic algae bloom and the death of thousands of Cassin's auklets, among other recorded impacts (Hakai, December 2016). Beyond these identified impacts the lasting outcomes of the Blob are not fully understood (Hakai, March 2016). However, research suggests that the event, and future events of increased SST (which are predicted to become more regular), could have dramatic influences on marine ecosystems and food-webs (Oliver, 2018). In regard to healthy and productive kelp forests, climatic events like the Blob are incredibly important. While kelp forests can acclimatize to SST changes through the season (Wernberg et al., 2010), their resilience when facing other stressors, such as storm activity, is reduced (Wernburg et al., 2010). The ways in which kelps will respond to variable climatic events like the Blob, and persisting increases in SST, is uncertain (Reed, 2016).

In addition to marine heatwaves other variables can severely impact kelp populations. Booming urchin populations (urchin herbivory, when unchecked by predators, can completely decimate kelp beds), resulted in a 90% decrease of kelp populations in California in 2014 (Roger and Bennett, 2019). Shrinking populations and diminishing health of kelp can have cascading effects on the many species that rely on kelp forests for shelter, food and other ecosystem services (Pfister et al, 2017; Catton et al, 2016). Some of these organisms include: sea otters, abalone, fish (such as juvenile salmon), seabirds and a myriad of invertebrates and microbial communities (Burt et al., 2018; Lemay et al., 2018; Berry et al., 2001). The integrity of marine ecosystems, specifically subtidal ecosystems, rely heavily on the health of kelp forests. Therefore, collapsing kelp populations are alarming and important.

Kelp forests are naturally dynamic, with populations fluctuating seasonally and annually (Sutherland, 1999). For this reason, long term data collection is necessary in order to correctly interpret populations shifts and identify natural versus anthropogenic drivers (Pfister et al., 2017). According to Hillebrand et al. (2018), "any substantial conclusion on biodiversity change…needs well-resolved and long-term continuous observation." For this reason, baseline and long-term monitoring are tools that can be used to: establish present-day information about species and ecosystems, increase our understanding of natural and anthropogenic impacts, predict possible outcomes of these impacts, reduce uncertainty, and improve management strategies. In kelp monitoring efforts, specific attention should be focused on the relationship between resilience of kelp populations and ecosystem services that they are able to provide.

Kelp Monitoring in the Pacific Northwest

There a number of kelp monitoring projects in the Pacific Northwest. The Washington State Department of Natural Resources monitors kelp using both aerial photography and water-based surveys (Berry et al., 2019). The Northwest Straits Commission also contributes to kelp monitoring in Washington State with volunteer-based kayak surveying (Bishop, 2016). In British Columbia, Mayne Island Conservancy has been mapping bull kelp extent around Mayne Island for 10 years, through a volunteer kayak program (Mayne Island Conservancy, 2019). Hakai has been undertaking aerial monitoring by both satellite and drones, in addition to SCUBA surveys of rocky-reef ecosystems (Hakai, 2018). Marine Plan Partnership for the North Pacific Coast (MaPP) brings together local bodies, such as First Nations Guardians and scientists in Northern coastal British Columbia to monitor kelp by kayak, motorboat, aerial surveys and SCUBA surveys (MaPP, 2019).

Kelp Monitoring in Clayoquot Sound

The stewardship and research of kelp, as an indicator species and primary producer in Clayoquot Sound has obvious relevance. Within Clayoquot Sound, there is currently no long-term kelp monitoring. In 2016, Strawberry Isle Marine Research Society (SIMRS) began to pilot a research project aiming to better understand how canopy forming kelps influence structures of invertebrate communities in the Clayoquot Sound. Though this project is not currently active, it initiated an important community conversation surrounding kelp, gathered community interest, and trialed monitoring methodology that we can learn from in future monitoring projects.

Pilot Study-Overview

This pilot study followed Mayne Island Conservancy's Guidelines and Methods for Mapping and Monitoring Canopy Forming Kelp in British Columbia, see Appendix-1 for full monitoring guideline and methods.

As noted above, there are a variety of ways to monitor canopy-forming. In August of 2019, Cedar Coast began a preliminary trial of Mayne Island Conservancy's kelp monitoring methodology around Vargas Island in Clayoquot Sound (see Appendix-1 and 2 for full monitoring guideline and methods). This monitoring approach is done by kayak unlike many other areal extent surveys that are done with aerial photography. This monitoring methodology aims to identify areal extents of kelp beds within a chosen region and subsequently outlines methods to monitor shifts in kelp populations over time. We expanded Mayne Island Conservancy monitoring to focus to both *N. luetkeana* and *M. integrifolia* because of the presence of both species in Clayaquot Sound. Therefore, we included the additional parameter of species identification to these existing methods.

Figure 2- Initial mapping of South Vargas

In order to find a location to conduct this trial we first conducted an informal survey by motor boat on the Southern portion of Vargas Island, South of Ahous Bay around the south end of the Island to Cedar Coast Field Station (located on the East side of Vargas Island), on August 14, 2019 (see figure 2). As the boat navigated the shore of the island two surveyors recorded visible kelp beds using the phone application Navionics, and marked waypoints corresponding to the general locations of visible kelp beds. Some additional notes were taken about beds, such as: location in relationship to the shoreline, density and general size. This survey was not exhaustive, there are most likely more beds within this area that we did not initially mark. This initial survey was then used to identify possible trial sites to map by kayak.

The location chosen to conduct the pilot study was identified for a few reasons. First off, we chose an area close to the field station that is both safe and easy to access by kayak. Second, the area chosen has a diverse range of kelp bed formations, with both near shore and off shore formations surrounding reefs shoals and islets. Lastly, after the first trial we found that this area has mixed beds of both *N. luetkeana* and *M. integrifolia*, which was an opportunity to identify the need for a species identification portion of the methods.

Pilot Study-Results

For this pilot we had two monitoring sessions. The purpose of the first trial day, August 18, 2019, was to test the repeatability of the monitoring methods. On this day two surveyors went out on the water to both measure one bed. During the first survey we thought that any bulb 5 meters off of the main bed was to be measured as an independent point or line. The actual methods define anything 8 meters away as an independent figure. For this reason, the maps made on the trial day one are different from the corrected maps on trial day two. Nevertheless, we were able to compare the two maps made by the two surveyors on day (figure 3). These maps show that two surveyors, mapping independently, can collect consistent data.

During day two we mapped an area with six individual beds in addition to various points and lines (see figure 4). Two factors, consistency and time were the main focuses of this trial. First, consistency has to do with the mapping between various surveyors. In our trial two beds were mapped by both surveyors, the other beds were just mapped by one. When a bed was mapped by both surveyors we found fairly consistent results between the two surveyors. The second factor in this protocol is time and tide windows. During our trial period we found that two surveyors were able to map a substantial area within a 3-hour low-tide window, as recommended by the guidelines and methods from Mayne Island Conservancy.

There are various environmental variables that influence kelp monitoring. One of the main issues we ran into was inability to survey some areas because of currents and rocky zones. We found that the kelp beds we mapped hugged rocky shores (shore or islet perimeter) closely, in these areas we were not able to kayak up against the rocks due to wave action. Ideally, we would be able to survey these zones while on the water. However, access is dependent on weather and tides. For the purpose of this trial we estimated the near shore perimeter of the beds using satellite imagery from Google Earth.

Pilot Study-Discussion

In the future, with project funding, monitoring can be advanced with more resources and time. While Navionics allowed us to mark relatively specific waypoints around the perimeter of the beds and experiment with factors such as time and consistency, hand-held GPS's should be used for increased precision. For the processing and mapping of this trial data we used Google Earth. With more time and resources, GIS programing would be ideal for long term data collection and analysis. In the future, additional resources such as a motor boat time and additional surveyors (paid or volunteer), will be needed for more exhaustive monitoring.

Various kelp monitoring methods: aerial surveying, SCUBA surveys, and on-water surveys with boats, each have differentiating benefits, drawbacks and purposes. As O'Neill and Costa (2015) argue in their review of satellite mapping of canopy-forming kelp, on-water surveying is both time and labour intensive. O'Neill and Costa call for the use of satellite imagery for mapping because it is more efficient method for large scale and time sensitive-areal monitoring. One of the major drawbacks of satellite mapping is that additional data (beyond areal extent), such as depth measurement and sea surface temperature, cannot be collected simultaneously as it can be with on-water surveys. A benefit is that satellite imagery is that can be used to map areas inaccessible by boat. Hakai conducts surveys via

SCUBA to monitor ecological changes to rocky-reef ecosystems with shifting ocean conditions, collecting data specifically about ecosystem composition. This specialized monitoring provides information that aerial and on-water surveys cannot. However, this method does not track over all areal shifts. Monitoring methods are not mutually exclusive, a mix of monitoring methods can be used in unison to bolster data collection when resources are available.

As outlined above, on-water surveying is one of many approaches to monitor kelp forests. A primary goal of this project is to develop a successful and long-term kelp monitoring protocol. A secondary goal is to share information and collaborate with other local organizations, which means that monitoring methods must be repeatable and accessible. Lastly, we hope that this project can be used as a tool for education and community building. Therefore, we have chosen this monitoring methodology specifically for its reliability, accessibility, and repeatability. There is room for other monitoring methods, such as aerial mapping, satellite imagery, or SCUBA, within this program if such resources are available or a scope of the project expands. Through Strawberry Isles kelp monitoring trials in 2016, we have learned that there are many local stakeholders in Clayoquot Sound interested in the wellbeing of kelp populations and recognize the importance of long-term kelp monitoring. Monitoring can be used as a tool for education and community building through citizen science and community collaboration. Long-term and large-scale monitoring throughout Clayoquot Sound will require involvement from multiple organizations and stakeholders.

Additionally, kelp monitoring can be tied to other work that Cedar Coast is already doing. For example, researchers have been conducting grey whale monitoring in Clayoquot Sound. Grey whales are often found feeding around and above kelp beds (Byatt, 2001). It may be possible to tie grey whale monitoring in with kelp bed monitoring. By collecting plankton samples in kelp forests as we map, we may be able to see trends in available food sources for these whales (Bishop, 2016). Other research projects, such as salmon monitoring, could also tie into the long-term monitoring of kelp.

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Appendix 1- Monitoring Parameters

The following Monitoring Guidelines (not including species identification) are sourced from the Mayne Island Conservancy.

There are a variety of parameters that can be measured in order to study changes in kelp beds and the surrounding environment. Mapping and monitoring programs can choose which parameters they incorporate based on their goals and their capacity to collect data. This section will outline these parameters and their relevance to monitoring strategy.

Location: Knowing the locations of kelp forest habitat is the first and most basic step towards recording changes and protecting these habitats. Fisheries and Oceans Canada follows a principle of "no net loss" to the productive capacity of habitats. If the locations of kelp forest habitats are recorded then this information may be used to protect them from the impacts of developments, which must either avoid impacting the productive capacity of habitat or provide compensation. Since *N. luetkeana* is an annual kelp, yearly reports of bed locations will help to establish knowledge of its recurring presence, and patterns of change. *M. integrifolia* persists year-to-year, therefore changes are likely to be in areal extent rather than location.

Delineation: Delineation of the boundaries of kelp beds will allow for monitoring to detect changes and patterns in the areal extent of kelp beds. For *M. integrifolia*, monitoring will track the expansion or contraction of beds, while for *N. luetkeana* it will track the areal extent patterns in which beds are re-established each year. This information can help to detect both anthropogenic and environmental impacts on kelp beds, as well as to understand natural fluctuations. Developments and activities that can be shown to negatively impact kelp forest habitat may be obligated to alter their practices or compensate for damages caused.

Depth Measurements: *M. integrifolia* and *N. luetkeana* both anchor themselves in the subtidal zone, with *M. integrifolia* growing relatively deeper than *N. luetkeana*. Both are constrained at their lower range by light avail-

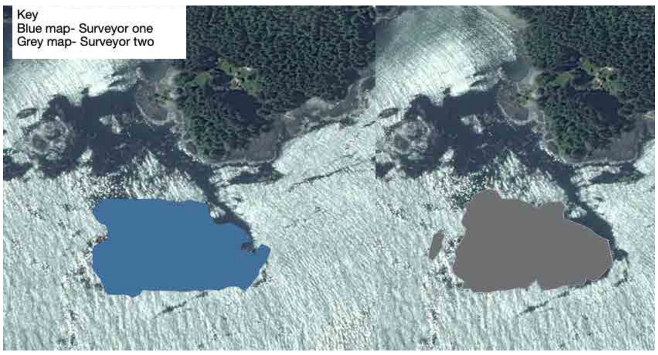


Figure 3- Comparative mapping of one bed. Trial day one (blue), corrected by altering bed-distance specifications on trial day two (grey).

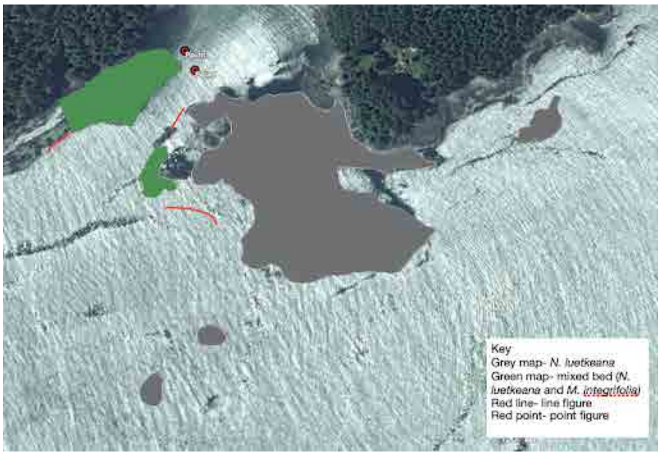


Figure 4- Trial day two. Mapping of full trial location, mapping done by both surveyors (not all beds repeated).

ability, and substrate type may also constrain their distribution. Thus, depth measurements may provide an indication of either substrate type or water quality. Runoff and pollution from coastal development can cause increased turbidity, decreasing the ability of kelps to photosynthesize in deep waters and decreasing their maximum depth. Yearly data regarding the maximum depth of kelp beds may provide an indicator of the changing health of the beds.

Sea Surface Temperature: Sea surface temperature is the main factor limiting the growth of kelp beds at the lower latitudes. Rising temperatures are also shown to have a negative impact on the extent of kelp beds at the mid latitudes. Kelps have been shown to respond metabolically to changes in ocean temperature, but this also results in a decreased resilience to additional stressors, such as storm activity or water pollution. Through El Niño cycles, temperature covaries with other conditions, such as upwelling which affects the abundance of nutrients replenished to kelp forest ecosystems. Sea surface temperature data will be helpful for observing correlations between environmental conditions and the abundance, distribution and health of kelp forest habitat.

Species Identification: *N. luetkeana* and *M. integrifolia* are both canopy-forming species present in Clayoquot Sound. Both species play an integral role in sub-tidal ecosystems, growing both independently and in mixed beds with one another. These two species thrive in similar environments, however, there are a few different factors that usually impact where these two species are commonly found. *N. luetkeana* grows well in open ocean environments with high-energy current and requires rocky substrata for its holdfasts to attach to. Therefore, it is not often found around protected or sandy coastal areas (Schoch, 2001). Similarly, *M. integrifolia* also persists in open ocean conditions, although it may prefer more sheltered areas, with rocky substrata. *M. integrifolia* does not often grow in areas with lower than open ocean salinity. Though *N. luetkeana* and *M. integrifolia* are similar algae the two species are fairly easy to differentiate, monitoring both species may help us have a clearer understanding of population dynamics and environmental changes over time.

Appendix 2- Monitoring Methods

The following Monitoring Guidelines (not including species identification) are sourced from the Mayne Island Conservancy.

The following methods are based on those used by the Mayne Island Conservancy to map kelp beds off the shores of Mayne Island from 2010 to 2018 (and beyond). They are provided here as a guideline for organizations and communities to map kelp beds in a consistent manner, using a standardized data entry form. They are designed to be carried-out on the water, using kayaks as the data collection platform and handheld GPS units to record waypoints.

Surveys should both be carried out between August 1st and September 31st each year, when bull kelp has grown to its full extent but has not yet begun to die back. This will help to maintain consistency of data collection bed-to-bed, region-to-region, and year-to-year. Data collection during mapping and monitoring should take place only within one hour before and after low tide, when the tide height for the entire two-hour interval is below a set level. Our data were collected with a tidal height 1.2m MLLW or less. This is the tide limit for the data collected by the Washington State Department of Natural Resources in its Nearshore Habitat Kelp Monitoring program, and thus serves as an established guideline that other kelp monitoring programs can follow, in order to maintain consistency and for data comparison (Britton-Simmons et al., 2008).

Feature Definitions: Kayak surveyors record three types of Features (Polygons, Lines, and Points) based on the following definitions. Features are mapped by recording waypoints every 4-6m around the perimeter (Polygons), or down the center of the feature (Lines and Points).

Polygons: Polygons represent kelp beds greater than 5m across. The edge of the bed is defined as the point at which the distance between kelp bulbs becomes greater than 8m. Bulbs separated by a distance of more than 8m are considered outside of the bed and should be recorded as a separate Feature. Paddle the kayak along the contours of the Polygon edge, recording waypoints every 4-6m, making attempts to accurately reflect the shape of the Polygon. Using the data collection sheets, write down the start and end waypoint numbers that correspond to each Polygon so that

Polygons can easily be drawn in the office using GIS software. The waypoints are used to geo-reference the boundaries of kelp beds and create a polygon, which can be used to calculate the area of the bed and compare that area to past/future years.

Lines: In some cases kelp may form continuous strips along the shoreline, or appear to form a Line. When less than 5m in width these strips should be recorded as Lines, with a single series of waypoints taken at intervals of 4-6m, or where the Line curves. A separation of greater than 8m between bulbs will mark the end of the current Line and the beginning of a new Feature. Use the data sheets to write down the start and end waypoint numbers that correspond to the beginning and end of each Line.

Points: Single bulbs or small clusters less than 5m in diameter can be marked as Points, by recording a single waypoint at the center. In keeping with the above guidelines for delineation of Lines and Polygons, solitary bulbs or small clusters will be considered on their own when they are separated from other bulbs by more than 8m. Clusters should be marked with a single waypoint unless they are greater than 5m across in which case it will be marked as a Polygon.

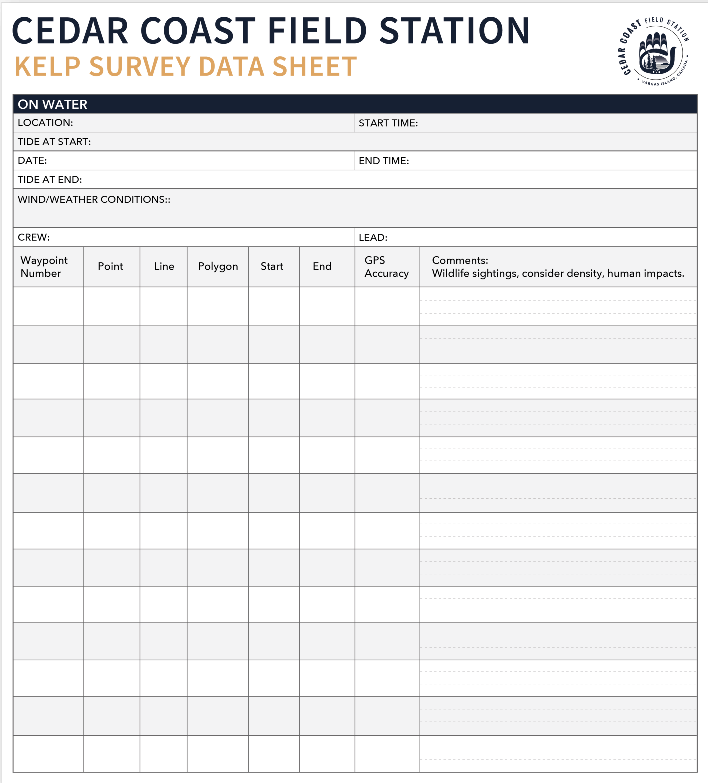
Species Identification: *N. luetkeana* has a holdfast that secures to rocks in the subtidal zone, a long stipe extends toward the water's surface where a buoyant, carbon monoxide-filled bulb called a pneumatocyst floats. Long blades, reach up to 10m extent from the pneumatocyst and sequester energy through photosynthesis. Often individuals are found twisted together in rafts. *M. integrifolia* is also found attached to rocky substrata with a holdfast, blades extending the full length of the stem. Every blade has a small pneumatocyst that floats toward the surface of the water.

Depth Measurements: A weighted measuring tape can be used to record depths along both the nearshore and far-shore edges of kelp beds. Depth measurements are recommended every 50m or as frequent as time allows. Let the weighted end of the measuring tape drop until it reaches the bottom, wind it up slightly, and then lower it to the point where it begins to slacken. Record the exact time of each depth measurement, so as to account for the tide height and obtain an absolute depth. Minute-by-minute tide information can be obtained from many sources, including: **http://tbone.biol.sc.edu/tide/sites_othernorth.html.**

Photo Record for Density: Photos can be used as a visual reference of the size of kelp beds. Each bed mapped should be photographed from a location that captures all or a large part of the survey area. The bearing of the photo (true north) and waypoint should be recorded at the location from which the photo was taken. This can provide a visual reference not only of the location and areal extent but also the density of kelp beds.

Recording Sea Surface Temperature: Ocean surface temperature data, collected over multiple years of monitoring, may provide helpful insight into year-to-year fluctuations in kelp abundance and distribution, and thus it is a useful indicator of environmental conditions affecting kelp. Kelp beds have been shown to fluctuate along with cyclical changes in sea surface temperature. Throughout El Niño cycles sea surface temperature also covaries with other conditions such as storm activity and upwelling which impact kelp abundance. Data on sea surface temperature could provide insight into patterns of natural fluctuations in kelp abundance in relation to cyclical changes in climatic and environmental conditions. Temperature can be recorded with a temperature logger attached to a buoy, but it also may be available from nearby government observation stations.

Appendix 3- Survey Data Sheet



CEDAR COAST FIELD STATION

KELP SURVEY DATA SHEET

ON WATER

LOCATION: | START TIME:

TIDE AT START:

DATE: | END TIME:

TIDE AT END:

WIND/WEATHER CONDITIONS::

CREW: | LEAD:

Waypoint Number	Point	Line	Polygon	Start	End	GPS Accuracy	Comments: Wildlife sightings, consider density, human impacts.

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