Bull Kelp Monitoring in Island County, 2015 - 2016
Island County Marine Resources Committee

 

 

Clockwise, from upper left:
Shiner perch (lower center) and forage fish school (right side) in bull kelp bed (L. Rhodes). Fried egg jellyfish, *Phacellophora* sp. (L. Rhodes). Kelp crab, *Pugettia* sp. (L. Rhodes). ICMRC volunteer surveyors on Polnell Point kelp bed, infrared imaging (V. Brisley)

Report submitted in partial fulfillment of WA Department of Ecology grant SEANWS-2015-IsCoPH-00004, Task 2 (kelp).

Project period: May 2015 – September 2016

Report date: September 30, 2016

Project lead: Linda Rhodes

Project participants: Barbara Bennett, Vernon Brisley, Barbara Brock, Paulette Brunner, Lenny Corin, Leal Dickson, Linda Kast, Don Meehan, Debra Paros, Gregg Ridder.

PUGETSOUND PARTNERSHIP
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I. Introduction

Kelp forests represent significant habitat for a wide variety of invertebrate and vertebrate animals, and may also influence other submerged aquatic vegetation (Mann 2000; Graham et al 2007). In addition to providing structural habitat, primary productivities of kelp forests match or exceed those of tropical rain forests, marine reefs and estuaries, and warm temperate forests (Mann 1972a; Mann 1972b). In Washington State, two species of kelp are dominant: giant kelp (*Macrocystis integrifolia*) and bull kelp (*Nereocystis leutkeana*). While both species occur along Washington's outer coast and coastal Strait of Juan de Fuca, bull kelp is the species found along shorelines of the inner Salish Sea (Mumford 2007).

Following a state-wide moratorium of commercial harvest of wild kelp and seaweeds in 1988, Washington State Department of Natural Resources (WDNR) initiated annual aerial surveys of coastal aquatic vegetation from Port Townsend Bay to the Columbia River. These surveys have continued for nearly every year, and in 2010, surveys were extended to include the resources of the Smith and Minor Island Aquatic Reserve (SMIAR), which is contained entirely within Island County. In the latest analysis of coastal kelp from 2013 to 2014 (excluding SMIAR), decline in planimeter area of bull kelp around Port Townsend was ~14%, and range-wide decline in planimeter area of both kelps was 38% (Van Wagenen 2015).

The earliest comprehensive evaluation of kelp resources was conducted in 1911, where over half of the total tonnage of bull kelp in the American portion of the Salish Sea was estimated to be located within the jurisdiction of modern Island County (Rigg 1915). Uncertainty about the distribution of bull kelp in areas not monitored by WDNR overlaid by anticipated changes in marine conditions attributable to climate are motivations to conduct an inventory and assessment of this resource in Island County. The Island County Marine Resources Committee (MRC) considered this to be an important activity to conduct under its sponsorship.

II. Scope of Project and Objectives

This report covers the project period from spring 2015 through late summer 2016. Work completed up through September 2015 was not funded through the MRC, while work performed up through mid-September 2016 was supported through the MRC's grant from the Northwest Straits Initiative Commission (NWSC). Not all of the 2016 data are included in this report, due to the report deadline.

Objectives for 2015 included:

1. Identify kelp beds to survey
2. Identify volunteers to conduct surveys
3. Test methods in a draft protocol for kayak-based surveys of kelp beds (protocol provided by NWSC)
4. Provide feedback to NWSC on draft protocol

Objectives for 2016 included:

1. Identify kelp beds to survey
2. Identify volunteers to conduct surveys
3. Incorporate protocol modifications for kayak-based surveys
4. Establish baseline data sets for selected kelp beds
5. Explore aerial imaging as a method for a comprehensive inventory of kelp beds

III. Project Progress

A. 2015 Progress

The project was initially led by Leal Dickson (MRC), a marine phycologist. At the beginning of the summer, Dickson needed to step back from the project due to health considerations, and Linda Rhodes (MRC) agreed to serve as project lead.

Objective 1: Identify kelp beds to survey.

In consultation with kelp expert Tom Mumford (Marine Agronomics LLC), Dickson selected three kelp beds for survey in 2015, named by the closest kayak launch location: Hastie Lake boat launch, Libbey Beach Park, and Ebeys Landing Park (Figure 1).

Figure 1. Approximate locations of kelp beds and names of beds surveyed in 2015 and 2016.

Objective 2: Identify volunteers to conduct surveys.

Volunteers for 2015 (in alphabetical order) included Vernon Brisley, Lenny Corin, Linda Kast, Don Meehan, Debra Paros, and Linda Rhodes.

Objective 3: Test methods in a draft protocol for kayak-based surveys of kelp beds (protocol provided by NWIC).

Each team of two kayakers selected one of the kelp beds to survey throughout the season. Teams conducted a June survey at a zero-foot tide, and a feedback meeting was held before July. Several issues and solutions were addressed and resolved at the June feedback meeting.

1. Safety: Teams surveying the Hastie Lake and Libbey Beach beds reported being in the surf zone at the zero-foot tide. Based on local knowledge, it was known that a 5-foot tide would avoid the problem, and that tidal height was chosen for those two beds. As a reference, the Ebeys Landing bed would be surveyed at both the zero-foot and 5-foot heights to understand the effect of tidal height on bed area.
2. No GPS data collection and management instructions: The protocol was not well written, lacking essential operational instructions but containing much irrelevant information. Teams were frustrated that no instructions were provided with the protocol or equipment from NWSC, requiring individuals to spend much time figuring out how to use the GPS. Also, information and equipment cords for downloading and managing data was not provided, again requiring individuals to figure it out. By the end of the meeting, rudimentary operational information had been shared among the teams.
3. No depth or temperature equipment: Teams were required to develop and/or purchase their own equipment. Non-standardized equipment introduces measurement variations. One volunteer (VB) developed a depth measuring system using marked cotton string, cotton sock, and rocks, which is inexpensive and biodegradable if accidentally lost, and he offered to make additional sets for teams.
4. Density count protocol: The NWSC protocol did not collect representative data for beds, particularly large beds, because the transect was fixed to a 10 random strokes set. The teams decided to scale the transect to the entire length of the longest axis for better representation. Other concerns focused on how bulbs were counted if in a tangle, direction and strength of current (which can pull bulbs underwater), effect of boat drift, effects of stopping and starting the boat, and similar real-world considerations in implementing the protocol. Although no unified method could be devised, each team agreed to try to be as consistent as possible throughout the season.

<u>Objective 4: Provide feedback to NWIC on draft protocol</u>.
Feedback to NWIC was provided in two ways.

1. A Powerpoint file containing data and key observations was provided for the kelp monitoring session of the 2015 Northwest Straits annual conference (November 6-7, 2015; Bellingham WA).
2. A kelp monitoring workshop was held by NWSC on December 5, 2015 in Port Townsend WA. Participants from IC included Vernon Brisley, Debra Paros, and Linda Rhodes.

B. 2016 Progress

<u>Objective 1: Identify kelp beds to survey.</u>
Several criteria were used to select prospective kelp beds for mapping in 2016.

1. Beds were not located in an unsafe location for working in a kayak.
2. Beds were not already surveyed annually by WA DNR.

3. Beds were located in proximity to ongoing or prospective biological monitoring.
4. Prior mapping data was available.
5. Beds were sufficiently large and/or dense to persist from year to year.

Using aerial photographs taken in 2015, Gregg Ridder found six locations with identifiable kelp beds, clearly visible at 2000 feet. Among these beds, two are located in proximity to sites receiving post-restoration monitoring (Cornet Bay, Ala Spit), and one site is proximal to a possible future restoration (Camano Island State Park). Prospective beds and final bed selections were based on the selection criteria, volunteer interest, and volunteer location (Table 1). These sites can also be observed on Figure 1.

Table 1. Prospective bull kelp beds for the 2016 survey.

Kelp bed name	**Nearest existing or future monitoring site (distance in km)**	**Prior data available**	**Selected for 2016**
Ben Ure Island	Cornet Bay (0.8)	No	Yes
Hoypus Point	Ala Spit (3.9)	No	Yes
Polnell Point	Maylors Point (5.3)	No	Yes
Lowell Point	Camano Island State Park (0.4)	No	Yes
Ebeys Landing	None	Yes	Yes
Harrington to Race Lagoon	None	No	No
Possession Point	Glendale Beach (4.1)	No	No

<u>Objective 2: Identify volunteers to conduct surveys.</u>
Volunteers for 2016 (in alphabetical order) included Barbara Bennett, Vernon Brisley, Barbara Brock, Paulette Brunner, Debra Paros, and Linda Rhodes.

<u>Objective 3: Incorporate protocol modifications for kayak-based surveys.</u>
The revised protocol from NWSC included several changes from the original protocol.

1. Bulb density estimates were permanently discontinued as a result of MRC feedback at the December workshop. This allowed us to greatly simplify the field data sheet and post-collection summary (see QAPP Appendix A).
2. The revised protocol requests photographs of the bed, but volunteers were expected to provide and place their own cameras at risk. Consequently, photographs were optional.
3. An assessment of kelp "health" was requested, but no training or documentation for assessing kelp health was provided. Because uninformed observations can lead to incorrect diagnoses or conclusions, this was not performed.

The minimum required data collection for the bull kelp surveys in Island County were:

1. Perimeter tracking data as per protocol at a zero-foot tide.
2. Depth and surface temperature measurements at an outer margin point, a mid-bed point, and an inner margin point of the bed.
3. Any observations of organisms utilizing the kelp bed during the survey.
4. Collection of data for at least two months in 2016 (June through September).

<u>Objective 4: Establish baseline data sets for selected kelp beds.</u>
Data collected well exceeded the minimum requirements, and these results are reported in the Data Results section. In addition, data collection was conducted to address specific questions about survey variation and logistical difficulties in mapping.

1. Inter-observer variation in area measurement.
2. Tidal height effects on area measurement.
3. Estimating inner margins in beds along rocky shoreline.

<u>Objective 5: Explore aerial imaging as a method for a comprehensive inventory of kelp beds.</u>
Inspection of the aerial images from the 2015 eelgrass survey for IC MRC raised the possibility of using aerial images for conducting an inventory of kelp bed locations throughout Island County. Because physical conditions such as sunlight reflection and wind-driven waves can complication kelp bed identification, several different approaches were examined to augment or improve aerial identification.

a. **Infra-red imaging**. Infra-red imaging relies on wavelengths reflected by chlorophyll pigments, and this technique is widely used to assess terrestrial vegetation. A more complex form of infra-red imaging was used by WA DNR in its aerial survey of aquatic vegetation starting in 1989, but has been subsequently discontinued. One of the volunteers (VB) converted a digital camera with an infra-red sensor, and showed that surface bulbs and fronds were visible from > 100 feet away (Figure 2). Pairing the infra-red camera with a visible light (RGB) camera of matched format and focal length offers an opportunity to use information from both systems for bed identification.

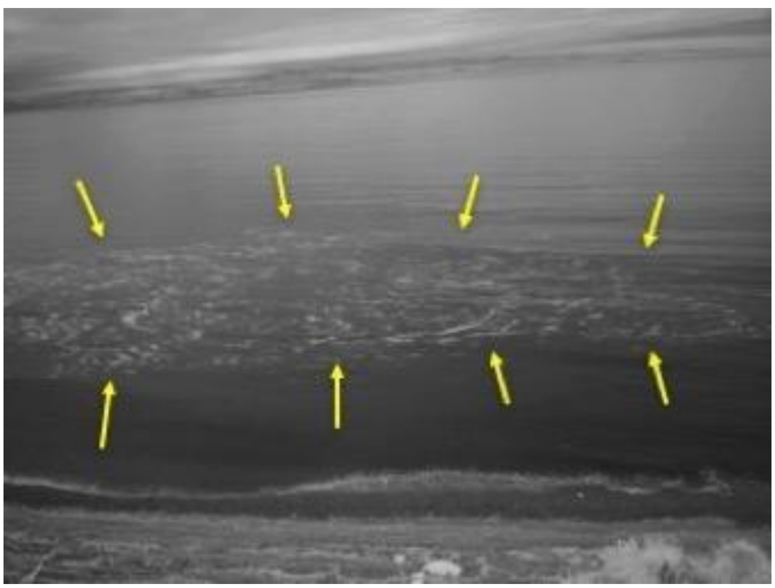

Figure 2. Infra-red image of kelp bed from nearby bluff showing surface bulbs and fronds (arrows). (Image by V. Brisley)

b. Paired orthogonal aerial photography. Gregg Ridder had already devised a housing for orthogonal (i.e., straight down) photography for the IC MRC eelgrass survey. One of the volunteers (VB) manufactured a similar housing for the infra-red camera, which was mounted on the opposite wing of the survey plane. Using synchronized shutter triggering, simultaneous orthogonal photographs can be taken. Images can be linked by georeferencing with a GPS. Next steps are to determine whether criteria and a pipeline for analysis can be developed.

c. Paired oblique aerial photography. Oblique photography is another potential application of paired visible light/infra-red imaging (Figure 3). To provide the maximum overlap in imaging, one of the volunteers (VB) manufactured a frame for holding both cameras at the same angle (Figure 4). Images are captured through a polarizing filter to improve clarity. Synchronized shutter triggering and linking through georeferencing allows image comparisons. Future efforts will determine whether criteria and a pipeline for analysis can be developed.

Figure 3. Paired orthogonal aerial photographs from ~ 2000 feet using visible light (RGB) and infra-red wavelengths. Arrow points at bull kelp on both images. Double asterisks (**) on infra-red image mark strong sun reflection, not kelp. (Images by G. Ridder, V. Brisley)

Figure 4. Paired visible light and infra-red cameras on a hand-held mount used for oblique aerial photography. Note polarizing filter on the airplane window. (Image by L. Rhodes)

IV. Data Results

Mapping efforts from both 2015 and 2016 will be presented in this section. **Due to the deadline for this report (September 30, 2016), some 2016 mapping information is not included, particularly September surveys.** All tracking and waypoints files (.gpx) are available from IC MRC's Dropbox (links provided below). Excel spreadsheets containing results are in Appendix A.

<u>Libbey Beach Park</u>
This bed was surveyed only twice in 2015, & surveys were discontinued in 2016 because the area is already surveyed by WA DNR. The bed area decreased between the June and July surveys, probably because the tidal height of the July survey was higher (Figure 5). In July, mean bed depth was 3.70 m and mean surface temperature was 11.1°C. Bulb density measurements in July were classified as "low" (0-3 bulbs m^{-2}).

Figure 5. Perimeters of the Libbey Beach Park kelp bed and bed areas surveyed in 2015.

<u>Hastie Lake Launch</u>
This bed was surveyed monthly from June through September 2015, but surveys were discontinued in 2016 because the area is already surveyed by WA DNR. Only the June survey was conducted at a zero-foot tide, due to safety concerns. The decrease in bed area between June and July is probably due to the change to a 5-foot tidal height for surveys (Figure 6). In July, mean bed depth was 4.40 m and mean surface temperature was 13.9°C. Bulb density measurements in July were classified as "low" (0-3 bulbs m^{-2}).

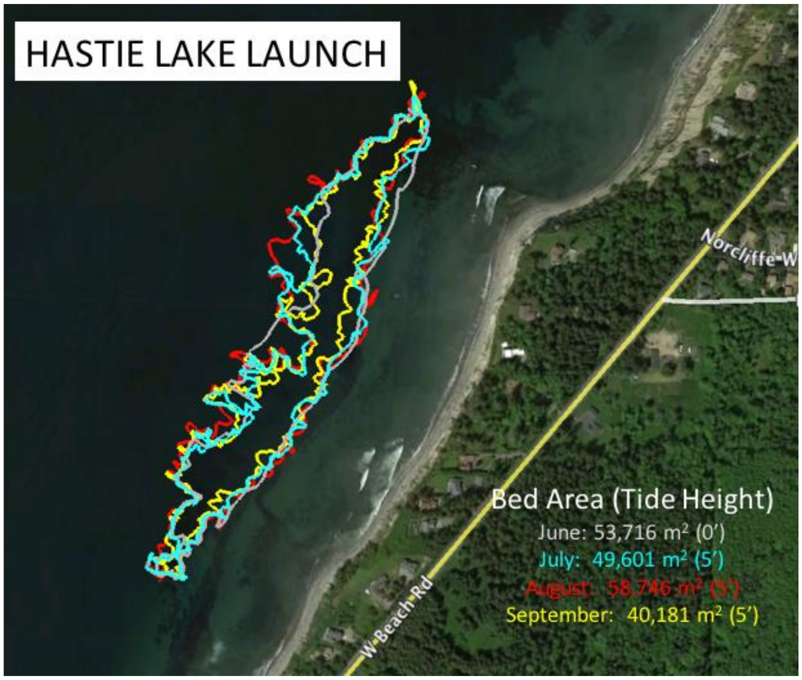

Figure 6. Perimeters of the Hastie Lake Launch kelp bed and bed areas surveyed in 2015.

Ebey's Landing

This bed has been surveyed in both 2015 and 2016. In 2015, mapping was done at two different tidal heights (zero-foot and 5-foot). The 5-foot height measurements in 2015 were conducted to provide a reference for the mapping performed at Libbey Beach Park and Hastie Lake Launch beds (see above). In 2016, mapping was performed at only the zero-foot height.

In 2015 at a zero-foot tide, a single bed was observed until September, when a second smaller bed appeared outshore from the main bed (Figure 7). At a 5-foot tide, however, the second bed was not visible at the surface and could not be mapped (Figure 8). Bulb density measurements for all four months in 2015 at a zero-foot tide were classified as "low" (0-3 bulbs m^{-2}). Density measurements at a 5-foot tide were lower than those measured for a zero-foot tide (Appendix A). Bed depth measurements during the zero-foot surveys ranged from a minimum of 1.2 m to 7.0 m, and mean bed depths ranged from 2.9 to 4.4 m through the 2015 season (Appendix A).

Figure 7. Perimeters of the Ebey's Landing kelp bed and bed areas at a zero-foot tidal height in 2015.

Figure 8. Perimeters of the Ebey's Landing kelp bed and bed areas at a 5-foot tidal height in 2015.

In 2016, the bed was larger at the beginning of the survey season than in 2015, with a peak bed area in July. By August, the bed area was similar in size to that in 2015 (Figure 9).

However, the temporal pattern of mean surface temperatures was dramatically different between 2015 and 2016 (Figure 9). Maximum mean surface temperature was in July 2015, but minimum mean surface temperature occurred in July 2016. Surface salinity measurements throughout the bed varied little, ranging between 33-34 ppt in July and August. Bed depth measurements ranged from a minimum of 1.4 m to 7.3 m, and mean bed depths ranged from 4.0 to 4.3 m during the 2016 season (Appendix A).

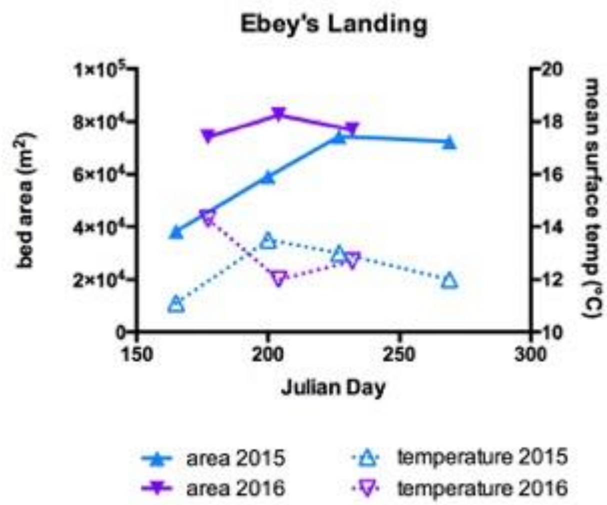

Figure 9. Plot of areas and temperatures at Ebey's Landing kelp bed in 2015 and 2016.

<u>Ben Ure Island</u>

This bed is located close to the restoration at Cornet Bay State Park, where extensive biological monitoring is conducted. The kelp bed is located very close to the rocky shoreline of Ben Ure Island, and obtaining a reliable inner perimeter is difficult. Several attempts at establishing a fixed shoreline margin have been performed, and this effort is discussed in a subsequent section. Preliminary estimates of bed areas show little change between June and July (Figure 10). For June and July, bed depth measurements ranged from a minimum of 0.3 m to a maximum of 4.4 m, with a mean depth of 2.2 to 2.4 m (Appendix A).

Figure 10. Perimeters of Ben Ure Island kelp bed and bed areas at a zero-foot tidal height in 2016.

Hoypus Point

This bed is located midway between Cornet Bay and Ala Spit, where another recent shoreline restoration project was completed. One zero-foot survey has been reported so far in 2016 (Figure 10). For July, minimum bed depth was 0.3 m, maximum bed depth was 4.4 m, and mean depth was 2.4 m (Appendix A).

Figure 11. Plot of perimeter of Hoypus Point kelp bed and area at a zero-foot tidal height in 2016.

Polnell Point

This bed is located at the eastern end of Crescent Harbor, and approximately 13 km from the south fork of the Skagit River. Temperature measurements at this site and at Camano Island State Park were dramatically higher than at the other sites (Figure 12). Surface salinities ranged between 20.5 ppt in early August to 29 ppt in late August. This bed exhibited the most dramatic increase in area of all the surveyed beds in both years. The increase was due to the appearance of a large, contiguous bed extending into Crescent Harbor (Figure 13). For the 2016 season, minimum bed depth ranged between 1.8 m to 4.0 m, maximum bed depth ranged between 3.7 m to 6.1 m, and mean depth ranged from 3.2 m to 5.3 m (Appendix A).

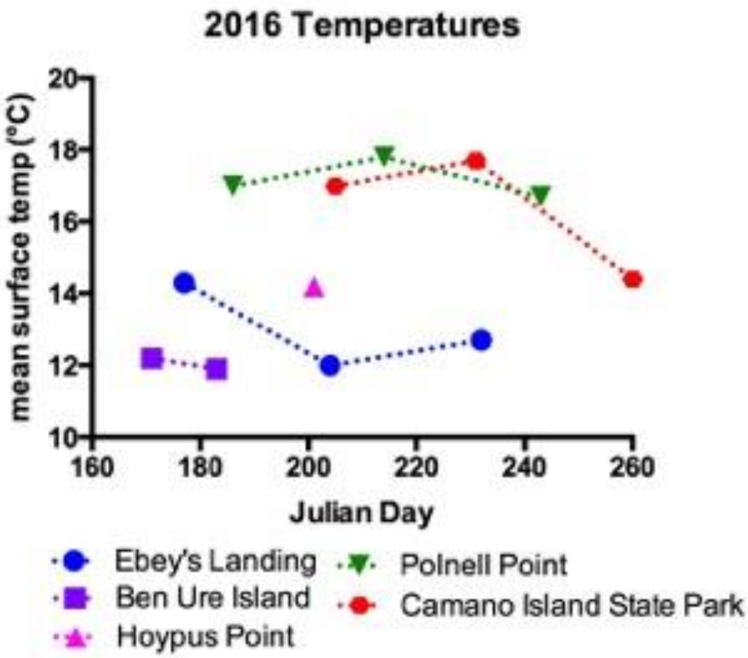

Figure 12. Mean surface temperatures at kelp beds throughout the survey season in 2016.

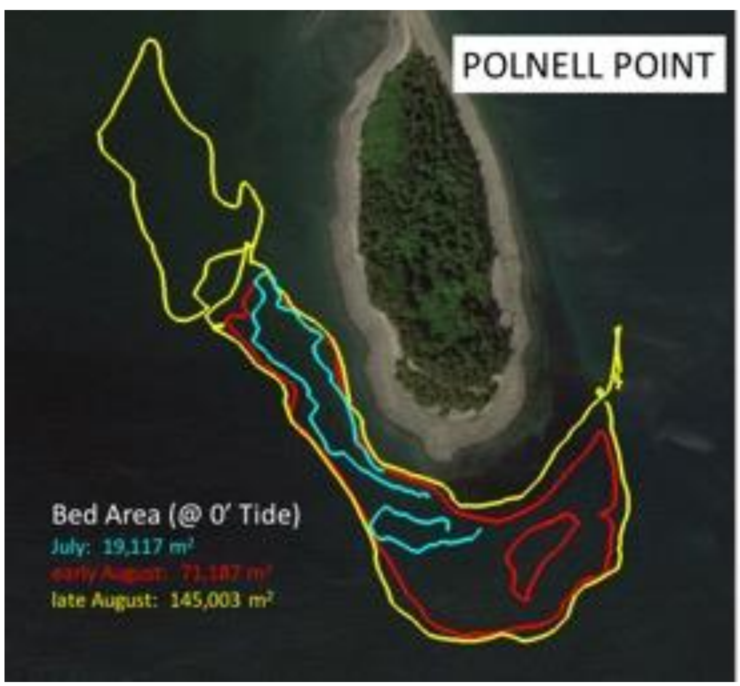

Figure 13. Plot of perimeters of Polnell Point kelp bed and area at a zero-foot tidal height in 2016.

<u>Camano Island State Park</u>
This bed is proximal Lowell Point which is adjacent to Camano Island State Park. A prospective restoration project at the park would connect a salt marsh within the park boundary to the shoreline. Currently, there is beach monitoring for forage fish eggs at the park beach. Temperatures were high and similar to those observed at Polnell Point (Figure 12), while salinity was at 26-27 ppt in July. Bed area exhibited a modest increase in area across the survey season (Figure 14). A second small bed north of the boat launch appeared in the September survey (Figure 14). Minimum measured bed depth in July and August was 1.8 m and maximum was 6.1 m, with a mean measured depths between 3.7 and 3.9 m (Appendix A).

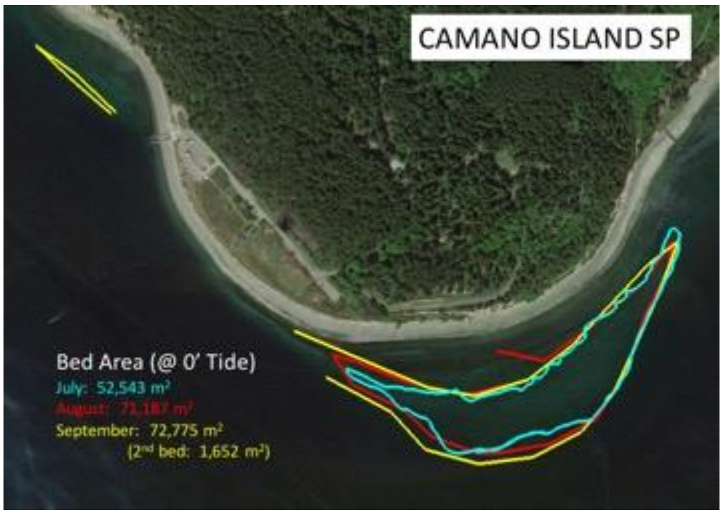

Figure 14. Plot of perimeters of Camano Island State Park kelp bed and area at a zero-foot tidal height in 2016.

Anecdotal observations in beds
Although the original (2015) protocol did not include observations of animals within the kelp during surveys, IC MRC volunteers made observations in 2015 and 2016 (Appendix B), and IC MRC volunteers recommended that it be included in the revised protocol. Observations ranged from harbor seals at Polnell Point, a variety of sea birds at all locations, and fish schools during certain months. Aggregations of perch, including shiner perch (Figure 15), were observed in beds with strong marine influence (Ebey's Landing) and beds with strong river influence (Polnell Point and Camano Island State Park). High densities of Dungeness crab zoea occurred in the Ebey's Landing bed in June 2015, but not in June 2016. Dense schools of juvenile forage fish, including Pacific herring (Figure 16), filled the Ebey's Landing bed in July and August 2016. Jellyfish were in low abundance at all beds in June, with a trend of increasing abundance through the summer, particularly at the Saratoga Passage beds. By August, fried egg jellyfish (*Phacellophora* sp.) were frequently observed organisms at the Polnell Point bed (Figure 17), and the public boat launch ~ 2 miles away contained > 100 beached jellyfish within a 50 ft stretch of beach, suggesting these jellyfish were abundant throughout southern Skagit Bay.

Figure 15. Shiner perch in kelp bed at Polnell Point. The circular bryozoan colony on the frond at the far right of the photograph is typical of the numerous colonies covering plants at this location in August.

Figure 16. School of juvenile herring in the kelp bed at Ebey’s Landing.

Figure 17. Fried egg jellyfish (*Phacellophora* sp.) in the Polnell Point kelp bed in late August 2016.

Comparison of bed areas in at a zero-foot tide (2015 and 2016)

Figure 18 displays the temporal patterns of all of the measured bed areas at a zero-foot tide. The smallest bed was at Ben Ure Island, while the largest was at Polnell Point. The bed with the most unchanged large area was at Ebey's Landing. The dramatic change in area observed at Polnell Point was not seen at Lowell Point near Camano Island State Park.

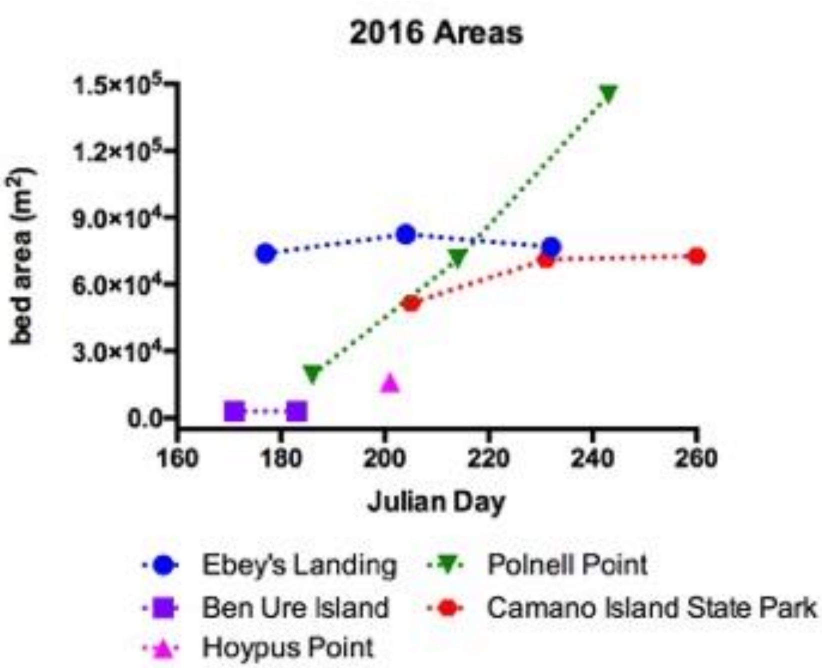

Figure 18. Comparison of bed areas for all sites surveyed in 2016 at a zero-foot tide.

Comparison of bed areas between individual surveyors
Due to the subjective nature of mapping perimeters, attempts were made to determine the range of variation among surveyors. Comparisons were made at the same date and time in the field. To minimize influence by the other individual, mapping was done either in opposite directions or were temporally offset by several minutes. Some comparisons were between individuals with extensive field time together, while other comparisons were between individuals with minimal field time together. Several comparisons were made when a more experienced surveyor was providing guidance instructions during the survey. Table 2 shows that inter-individual measurements can vary considerably. However, it suggests that training together can reduce the variation to less than 10%.

Table 2. Comparison of areas (m^2) mapped by different individuals at the same time and location, and the amount of shared field experience between individuals.

Site	Shared field experience	Individual #1	Individual #2	Percentage difference
Hastie Lake Launch	Minimal	40,181	53,307	24.6
Ebey's Landing	Extensive	82,492	77,450	6.1
Camano Island State Park	Guidance instructions during survey	53,532	51,543	3.7
Polnell Point	Minimal	19,117	23,916	20.1
Polnell Point	Guidance instructions during survey	71,187	69,648	2.2
Polnell Point	Partial guidance during survey	96,445	95,963	0.5

Effect of tidal height on measured bed areas

LA zero-foot tidal height was the desired target tidal height because it best matches the tidal height used in WA DNR surveys. Mapping at precisely a zero-foot tidal height is not always possible, because surveys are not instantaneous – a single mapping event can take up to 40 minutes for a large bed. Furthermore, getting onto the kelp bed at the exact time may not Poppossible or feasible. Differences in tidal height at the time of mapping is expected to affect bed areas, depending on stipe length. To better understand the effect of tidal height on bed areas, comparisons were made. For the Ebey's Landing comparison, measurements were made on the same day. For Hoypus Point, measurements were made two days after the zero-foot measurement.

Table 3 clearly shows that even a one-foot tidal height difference can have significant effects on mapped area. In the case of the 2016 comparison at Ebey's Landing, the difference both measurements were made in tandem, and the time separating the measurements was less than an hour.

Table 3. Comparison of areas mapped at different tidal heights.

Site	Zero-foot tidal height area (m^2)	Alternate tidal height area (m^2)	Alternate tidal height (ft)	Percentage difference
Ebey's Landing (2015)	59,151	48,419	5	18.1
	74,302	56,004	5	24.6
	79,992	64,460	5	10.9
Ebey's Landing (2016)	76,781	95,074	-1	19.2
Hoypus Point (2016)	16,315	4,581	6	71.9

Estimating inner perimeters of rocky shorelines
Some kelp beds are directly adjacent to rocky shorelines, and paddling the inner perimeter is hazardous. If the shoreline plotted on maps is not correct, as it is for Ben Ure Island (Figure 19A), an alternative approach for determining the inner perimeter is needed.

One approach is to mapping the shoreline at the zero-foot tidal height by walking. For Ben Ure Island, this was possible from the southern side to the eastern tip of the island and a track was created for this part of the Island (Figure 19A). However, the northern side of the Island is steep and not accessible on foot. Another approach is to create a series of waypoints from the outer perimeter using a laser rangefinder. This was attempted using an inexpensive unit (range up to 50 feet) at Ben Ure in August, marking each measurement with a waypoint (Figure 19A).

These data were provided to Suzanne Shull (WA DOE), and she was able to construct an inner perimeter from the combined information (Figure 19B), providing proof-of-concept for applying these methods to kelp beds with inner perimeters that cannot be tracked from a kayak.

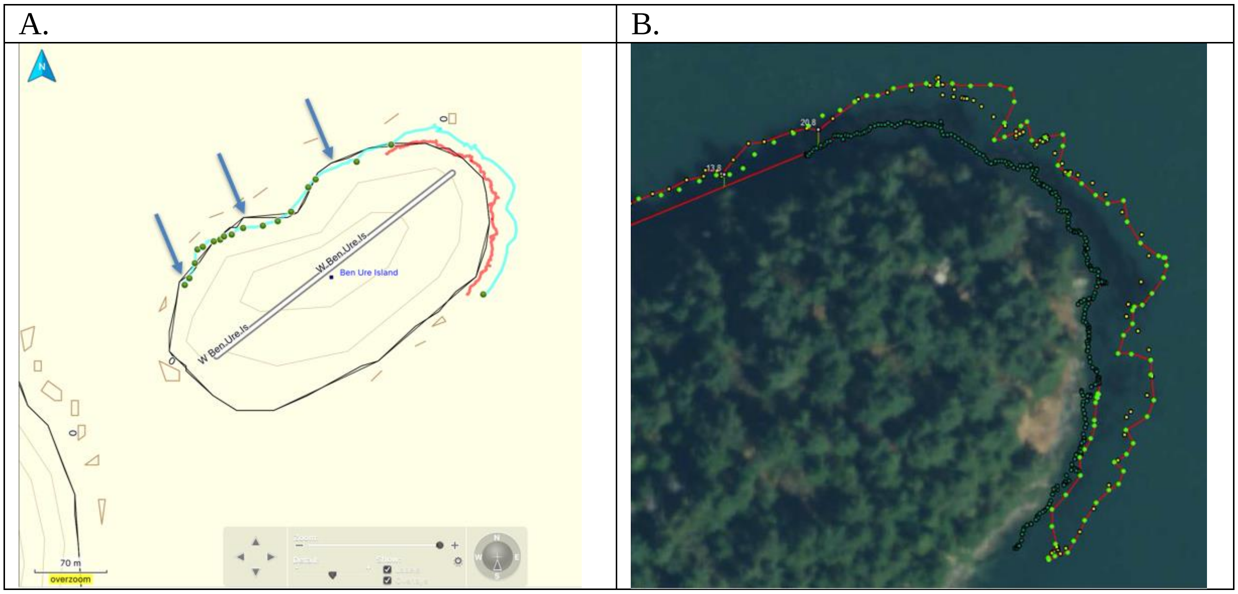

Figure 19. Estimating inner perimeters in difficult locations. A) Plot of kelp bed perimeter at Ben Ure Island (2016), showing inaccuracies in electronic shoreline (arrows) crossing the outer perimeter (cyan track), track created by walking the shoreline (red track), and waypoints where measurements to the shore using an inexpensive laser rangefinder were made (green dots). B) Inner perimeter constructed by Suzanne Shull from combination of walked track and rangefinder waypoints.

V. Discussion

Bull kelp bed observations

The potential for bull kelp forests to serve as critical habitat for both finfish and marine invertebrates has highlighted the gap in knowledge about the distribution and sizes of kelp beds in the Salish Sea. The marine waters around Island County contain some of the largest known kelp beds in or adjacent to Puget Sound, and some of these beds were recognized at the beginning of the last century when George Rigg conducted boat-based surveys of kelp beds along all of Washington State's coast in 1911 and 1912. Using an estimate of ~ 30 pounds per kelp plant and density estimates ranging from 0.75 to 1.25 plants per ft^2, Rigg calculated that approximately 100,000 tons of bull kelp resided around Smiths Island, which is contained within the current Smith and Minor Island Aquatic Reserve (Rigg 1915). The Smiths Island beds represented over 75% of the harvestable bull kelp identified in Puget Sound and the San Juan Islands at that time. Currently, the beds of the Smith and Minor Island Aquatic Reserve are surveyed annually by WA DNR by aerial photography.

However, little is known about Island County kelp beds outside of the Aquatic Reserve. We developed a series of tasks to begin to address this deficiency. First, prominent beds amenable to *in situ* assessment by boat were identified from aerial imaging. We took advantage of imaging conducted by Gregg Ridder for another MRC project, the annual eelgrass survey. Using his 2015 aerial photographs, Ridder identified larger kelp beds as candidates. Additional criteria for candidate beds were proximity to on-going monitoring (e.g., forage fish surveys, beach seining); proximity to past or prospective restoration projects; and availability of prior kelp survey data. Five of the seven candidate sites were surveyed in 2016, based on volunteer interest and ability.

In 2016, bed areas ranged over two orders of magnitude. The beds in Saratoga Passage (Camano Island State Park and Polnell Point) exhibited the largest increases in area during the survey season, while the bed in Admiralty Inlet (Ebey's Landing) showed relatively small area changes (Figure 18). Salinities in Saratoga Passage were lower, ranging from 20.5 to 29 ppt at Polnell Point, while salinities at Ebey's Landing were consistently ≥ 33 ppt. Conversely, mean surface temperatures in Saratoga Passage were much higher than at the other sites (Figure 12), approaching levels lethal to bull kelp (Pacific Gas and Electric 1987). Therefore, it is possible that kelp beds in Saratoga Passage are subjected to chronic thermal stress. However, the rapid growth and larger bed areas suggest these plants may have adaptations to conditions in Saratoga Passage. Surveyors informally observed that stipes and bulb appeared smaller and the color of the plants seemed lighter than those in Admiralty Inlet.

The only site with two years of mapping information was Ebey's Landing, and the patterns between the years were different. Bed area was larger and apparently peaked earlier in the year in 2016, possibly due to higher surface temperature (Figure 9). Temperature then declined by 2°C, and by the August survey, both temperature and bed areas were very similar between the two years. These observations suggest temperature or a correlated parameter can contribute to rapid growth in spring and early summer.

Anecdotal observations by surveyors in the kelp beds represent a source of information about the habitat value of the beds. This type of documentation can augment existing literature or professional scientific surveys, and it has the potential to identify utilization by novel species. There is marginal guidance in the revised protocol for collecting this information, and even the possibility of collecting inaccurate information. For example, the revised protocol requests information about the health of the kelp plants, but provides no resources or training on how to assess kelp health.

Assessment of citizen science

This project was originally proposed to the MRC as a citizen science opportunity. After two survey seasons, there is little evidence to support that this is a good citizen science project. First, project planning failed to develop well defined field activities. For example, bulb density estimation was included in the original protocol, but the proposed methodology was inadequately tested. Excessive volunteer time was wasted in trying to improve a method that was inherently flawed. This resulted in a high level of dissatisfaction among volunteers, and questioning the purpose of the project. The protocol is weakly written, and the proposed data sheet does not lead surveyors through the required steps, strongly indicative of a lack of field experience or scientific knowledge. Second, the technical expertise and equipment to accomplish the surveys requires significant training and coordination. In 2015, no instructions or even sufficient equipment (e.g., cords to transfer files from the GPS unit to computers) was provided, requiring volunteers to independently figure out how to operate the equipment and collect data. The expectation of volunteer teams to share GPS units is unrealistic, reflecting a lack of knowledge about the requirements for conducting the field work. Even into 2016 there was poor support for basic equipment to collect data, such as a depth measuring device. Finally, there is a lack of properly defined scientific objectives. A dominant question among volunteers has been about how data will be used or how results will augment or complement existing observations. The response that it will be posted to Sound IQ in not adequate nor a scientific objective. This leads to the conclusion that a scientific question will be formulated to fit the observations, rather than the observations addressing a scientific question.

Utility of boat-based surveys

We tried to address some of the sources of variation inherent in GPS mapping while collecting data. One source is person-to-person subjectivity in establishing a bed perimeter. We found that two individuals who had minimal time working together could generate widely different values, up to 25%. However, increasing the amount of time together in the field and sharing decision-making criteria can decrease those differences to well below 10%. While that can improve reproducibility for a specific kelp bed, it does raise an issue about comparing areas of beds surveyed by different teams. For IC MRC, four of the five beds surveyed in 2016 were visited by one team at least once during the season. Those visits included training and sharing decision criteria, so there is a higher degree of confidence that comparing bed areas (e.g., Figure 18) for this effort is reasonable.

Another source of variation is the tidal height at survey. In 2015, safety considerations forced volunteers at two sites to conduct surveys at a higher (5 ft) tidal height, instead at a zero-foot height. Surveys at the third site were conducted at both tidal heights to understand the impact on survey data. As expected, survey areas were small at the higher height, but there was no consistent relationship between heights and areas that would permit surveys to be conducted at varying tidal heights. Furthermore, bed definition became more difficult at higher tidal heights. In 2016, additional survey efforts reinforced these conclusions. In fact, in one instance a difference of ~ 40 min in survey time and 1 ft in survey height resulted in a nearly 20% in area. This indicates that survey data can be strongly altered by timing and tidal height, making consistent and reliable data collection difficult.

For obvious reasons, boat-based surveys have low utility in constructing an inventory of kelp beds within a jurisdiction. As a result of this two-year effort, we propose to use aerial imaging to identify kelp bed locations throughout Island County's waters and to classify beds by size subjectively. When available, we will use infra-red imaging in conjunction with visible light photography to correctly identify bull kelp. From this inventory, we can select beds for possible boat-based surveys to address well-formulated scientific questions.

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