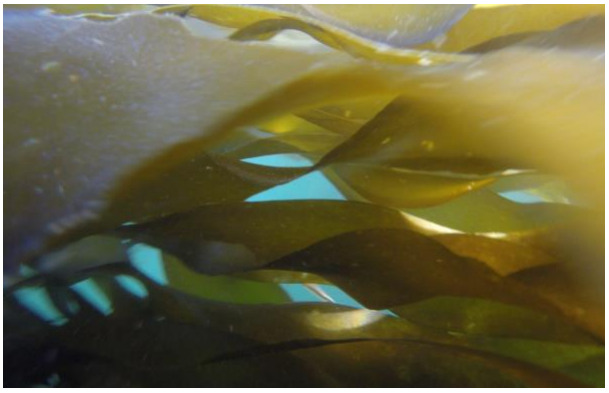
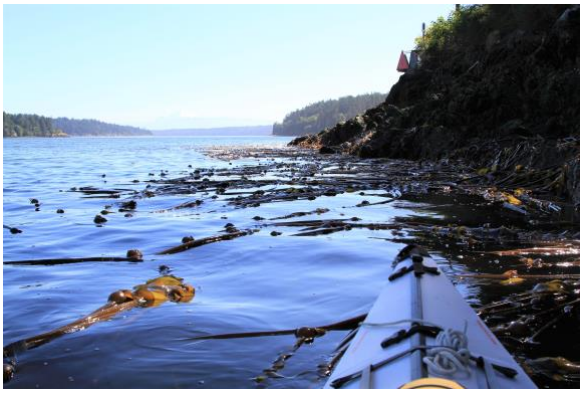
Bull Kelp Monitoring in Island County, 2018
Island County Marine Resources Committee



Clockwise, from upper left:
Kelp crab at Possession Point (R. Beier). Pile perch at Polnell Point (L. Rhodes). Bull kelp bed around Ben Ure Island (D. Paros). Bull kelp blades at Ebey's Landing (L. Rhodes).

Report submitted in partial fulfillment of WA Department of Ecology grant SEANWS-2018-IsCoPH-00005, Task 2.2 (Monitoring: Kelp)
Project period: October 2017 – September 2018
Report date: April 14, 2019
Project lead: Linda Rhodes
Project participants
Kayak surveys: Ron Beier, Barbara Bennett, Vernon Brisley, Debra Paros, Linda Rhodes, Tim Verschuyl
Aerial imaging: Gregg Ridder, Vernon Brisley

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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. Efforts were initiated in 2015 to select kelp beds and test a kayak-based survey protocol. These efforts were expanded in 2016, and have continued through 2017.

II. Scope of Project and Objectives

This report reports on the project period from fall 2017 through late summer 2018. Boat-based surveys and aerial imaging occur from early to late summer, often through September. Due to the close co-incidence of the end of the field season and the report deadline, not all of the 2018 data is included in this report.

Objectives for 2018 included:

1. Collect data from previously surveyed kelp beds by boat-based surveys to extend observations from 2015, 2016, & 2017.
2. Conduct aerial imaging of the Island County coastline for detecting kelp beds.
3. Compare thermometers used for surface measurements against NIST-certified thermometer.
4. Use temperature loggers to collect demersal temperature data.
5. Collect images of animals and plants within the kelp beds.

III. Project Progress in 2018

Objective 1. Collect data from previously surveyed kelp beds by boat-based surveys.
The four beds that were surveyed in 2016 and 2017 were also surveyed in 2018: Ebey's Landing, Ben Ure Island (Cornet Bay State Park), Hoypus Point, and Polnell Point. A fifth bed, Possession Point, that was assessed in August 2017 was surveyed monthly in 2018.

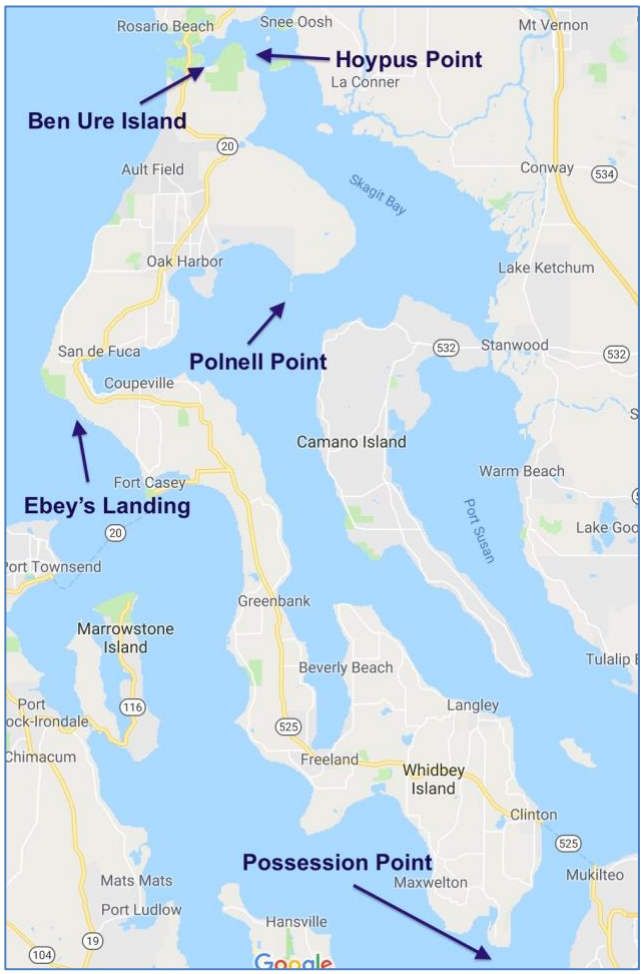


Figure 1. Approximate locations of kelp beds and names of beds surveyed in 2018.

Objective 2: Conduct aerial imaging of the Island County coastline for detecting kelp beds.
Much of the flight protocol had already been developed by Gregg Ridder for the MRC's eelgrass surveys. For kelp imaging, two major adjustments to the eelgrass protocol were made. First, flights are conducted in August or September, when beds achieve maximum area for the year. Second, a paired near infra-red (IR) camera was added to the visible light (RGB) camera to allow discrimination of surface vs submerged kelp, and to improve accuracy of identification.

Objective 3: Compare thermometers used for surface measurements against NIST-certified thermometer.
The accuracy of the thermometers used for collecting surface temperature was never determined by the protocol developers. Because many of the reported temperatures are close to or exceeded experimentally determined thresholds for negative effects on zoospore viability, we decided to compare measurements against a NIST-certified thermometer. Furthermore, comparisons were made before and after the survey season to determine whether there is drift in the measurements.

Objective 4: Test temperature loggers to collect demersal temperature data.
In order to collect temperatures at or near the bottom, Onset programmable temperature loggers were used at two sites (Ebey's Landing and Polnell Point). Attempts were made to collect bottom temperatures at least in two locations within the bed.

Objective 5: Collect images of animals and plants within kelp beds.
In 2017, we collected images of submerged aquatic vegetation (SAV) with a small scale drop-camera rig using a GoPro which was deployed from a kayak. Videos and photos were shared with knowledgeable staff at WA Department of Natural Resources, who indicated the quality was sufficient for SAV identification. However, there are no trained or qualified individuals available for reviewing video and photos. As a result, drop-camera image collection was discontinued, and we returned to using a pole-mounted camera for underwater imaging.

III. Boat-based Survey Results

Ebey's Landing

This bed is located outside of entrance to Admiralty Inlet, and it has been surveyed for four consecutive years (2015, 2016, 2017, 2018). As expected for a site with strong marine influence, surface salinities narrowly fluctuated between 32.5 and 34 ppt. Composite visible (red-green-blue or RGB) and near infra-red (NIR) images taken on September 6, 2018, show that much of the kelp that is visible at low tide is actually at the surface (Figure 2).

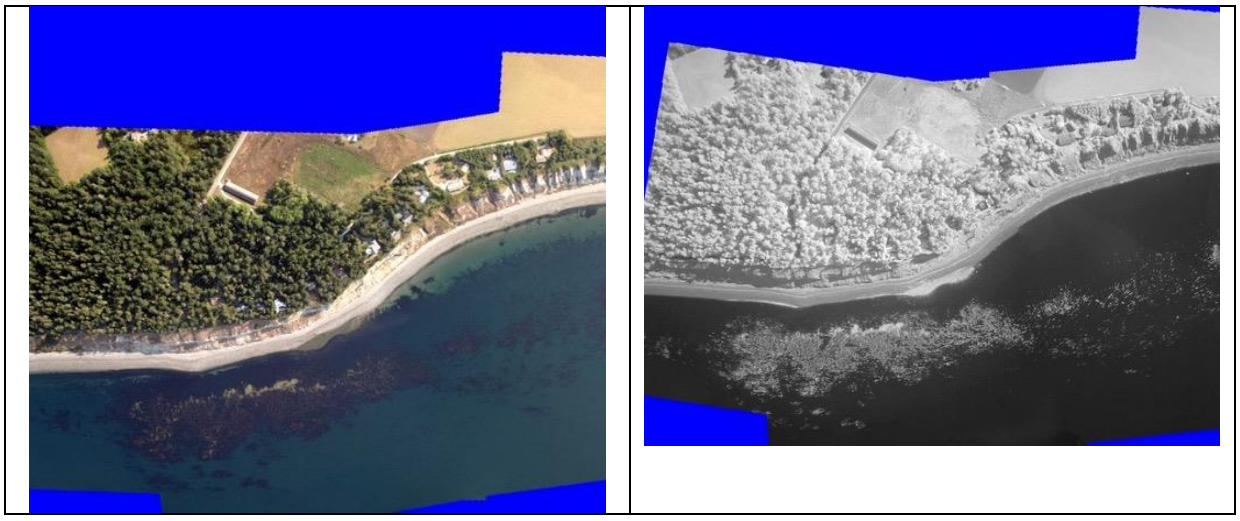
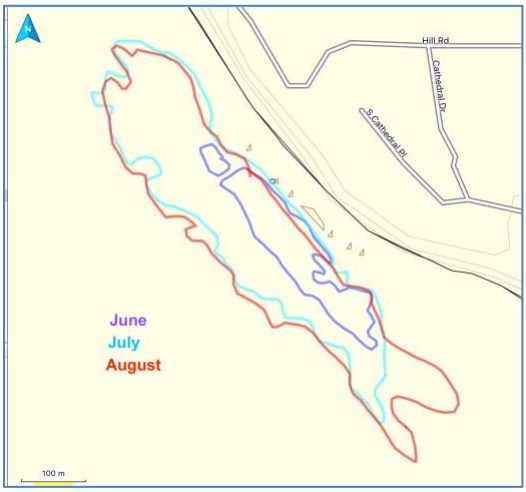


Figure 2. Ebey's Landing bull kelp bed on September 6, 2018, contrasting appearance in visible light (left) with near infra-red (right). Note that most of the kelp is visible at the surface in the near infra-red image. Photos by Gregg Ridder and Vernon Brisley; composite by Gregg Ridder.



There was a consistent increase in bed area from June through August (Appendix A), with a progressive expansion of the bed margin (Figure 3). Due to unfavorable weather conditions and personnel limitations, the bed was not surveyed in September (Figure 3).

The largest bed area occurred in August, with a total of 86,136 m2 or 21.28 acres (Appendix 1).

Figure 3. Monthly perimeters of the Ebey's Landing kelp bed and bed areas at a zero-foot tidal height in 2018.

Ben Ure Island (Cornet Bay State Park)

This bed is located in Deception Pass and close to the restoration at Cornet Bay State Park, where extensive biological monitoring (eelgrass, forage fish spawning) is conducted. The kelp bed is located very close to the rocky shoreline of Ben Ure Island (Figure 4).

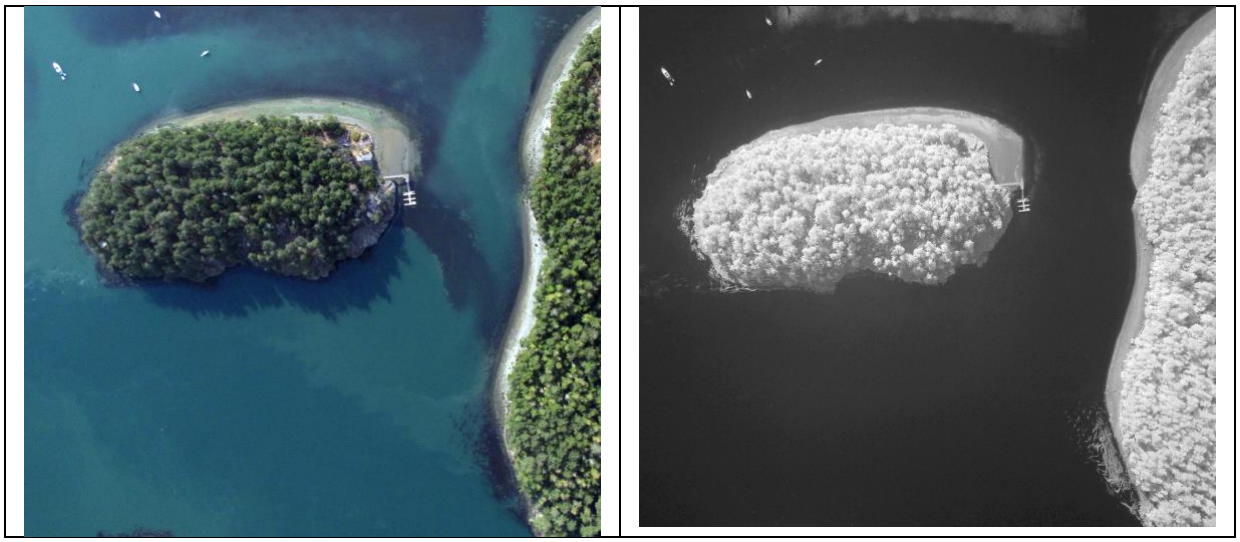


Figure 4. Aerial photographs of the Ben Ure Island kelp bed on September 6, 2018. Bull kelp is visible as a narrow band along the lower margin of the island in both the RGB (left) and NIR (right) images. The bed along the shoreline in the lower right was not included in the survey. Photos by Gregg Ridder and Vernon Brisley.

A problem with steep rocky shorelines is obtaining a closed track, because the inner perimeter cannot be safely paddled or walked. Even GIS products such as topological maps and LIDAR imaging may not generate an accurate shoreline that can be used as an inner margin. This means that area determination is not feasible. However, one meaningful evaluation is a comparison of the outer GPS tracks. A comparison of the June and July outer tracks does show an expansion of the bed farther from the island (Figure 5). Although an August survey was conducted, it was not yet available for this report, but will be included in the full annual report.

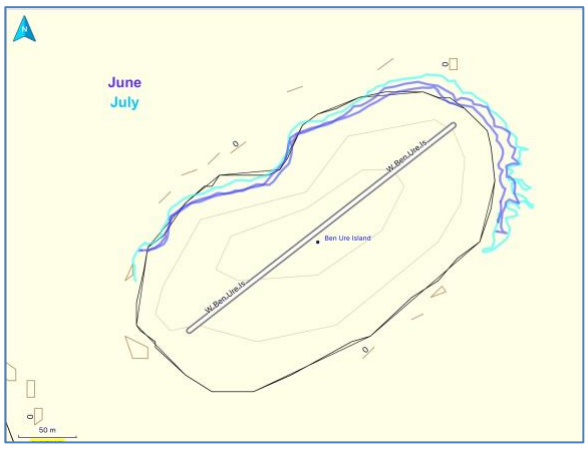


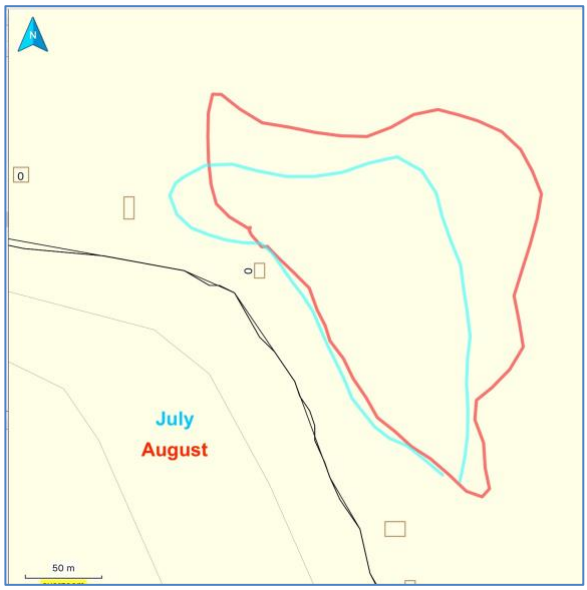
Figure 5. Monthly perimeters of Ben Ure Island kelp bed and bed areas at a zero-foot tidal height in 2018.

Hoypus Point

This bed is located at the eastern end of Deception Pass, midway between Cornet Bay and Ala Spit. Hoypus Point is likely to receive strong pulses of marine water during flood tides and river water during ebb tides due to its location. A significant aspect of this bed is that juvenile Chinook salmon from the Skagit River system often congregate around Hoypus Point during their ocean migration. The bed could serve as refuge for forage fish or other prey for emigrating salmon. One interesting feature is the convergence of two opposing drift

cells, creating a dynamic underwater sand bar that has bull kelp on one side and submerged aquatic vegetation on the other side (Figure 6).

Figure 6. Bull kelp bed at Hoypus Point on September 6, 2018. Bull kelp is clearly visible to the one side of the sand bar in both the visible light (left) and near infrared (right) images. Close examination of both images shows that the dark patch on the other side of the sand bar is submerged aquatic vegetation other than bull kelp. Photos by Gregg Ridder and Vernon Brisley



Although the bed was surveyed in June, and surface kelp was observed, equipment malfunction precluded obtaining a perimeter track. Bed area clearly increased between July and August (Figure 7). The western end of the bed appeared to shift between the two months, an observation made also in 2017. Changes at this end of the bed may be a result of active sediment movement around the sand bar.

Maximum bed area was measured in August, with an area of 30,287 m^2 or 7.48 acres (Appendix A).

Figure 7. Monthly perimeters of Hoypus Point kelp bed and area at a zero-foot tidal height in 2017.

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. The bed is clearly within the influence of the large freshwater influx, as surface salinities across the sampling months ranged between 16 - 24 ppt in 2016,

15 - 30 ppt in 2017, and 19 - 30 ppt in 2018. Comparison of visible light and near infrared images of this bed shows that by September 6, 2018, most of the bed is strongly expressed at the surface (Figure 8).

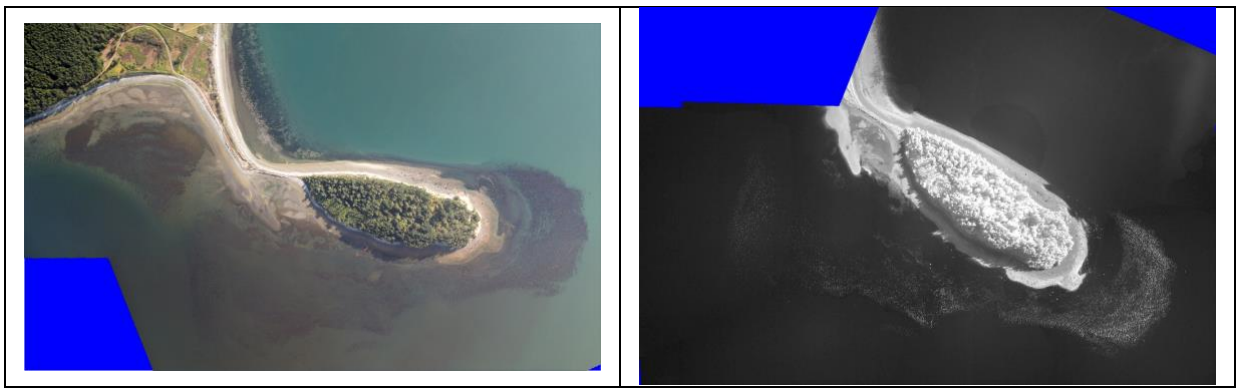
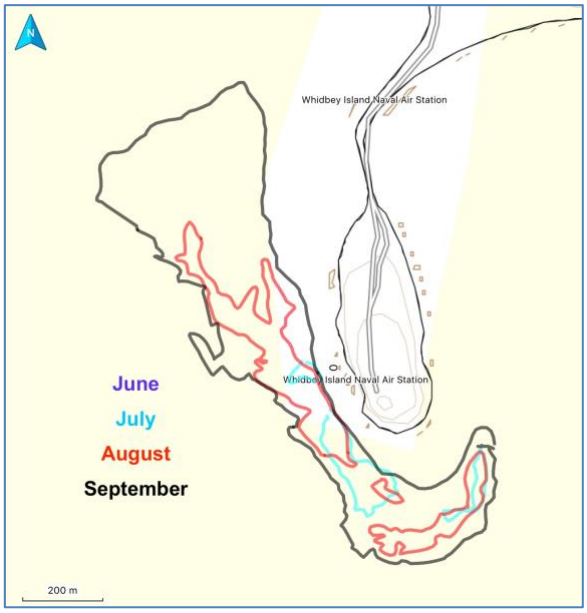


Figure 8. Polnell Point bull kelp bed on September 6, 2018, showing the large area of the bed. Photos by Gregg Ridder and Vernon Brisley; composite by Gregg Ridder.

As observed in previous years, the bed at Polnell Point emerges at the surface relatively late in the season. Only a few bulbs were at the surface during the June survey (no measurable perimeter). Scattered foci of kelp appeared in July and August, and these foci had connected and expanded by September (Figure 9). The Polnell bed reached the largest area measured of all beds for all 4 years (Appendix 1). Examination of the perimeter tracks suggest that the bed changed in distribution between July and August in the area southwest of the point. However, water current and tidal rips typically occur around the predicted "slack water" time off the point. It was observed that bulbs and blades can be held underwater for temporary periods (e.g., 10 minutes) during "slack water", potentially removing them from survey criteria.



Largest bed area occurred in September with a total of 300,040 m^2 or 74.14 acres (Appendix 1).

Figure 9. Monthly perimeters of Polnell Point kelp bed and area at a zero-foot tidal height in 2018.

Possession Point

This bed is located south of Possession Point and at the convergence of Admiralty Inlet, Central Puget Sound, and Possession Sound. As a result, it is likely to receive fluctuating influences of marine waters and river inputs daily. Possession Point is an extremely popular

salmon fishing location, which may be a due, in part, to its kelp bed. Although aerial assessment has identified kelp beds on either side of the Cultus Bay outflow, the surveyed bed is located to the east of the outflow and bounded by a stationary aid to navigation. By late August, a significant and complex bed was observed at Possession Point (Figure 10).

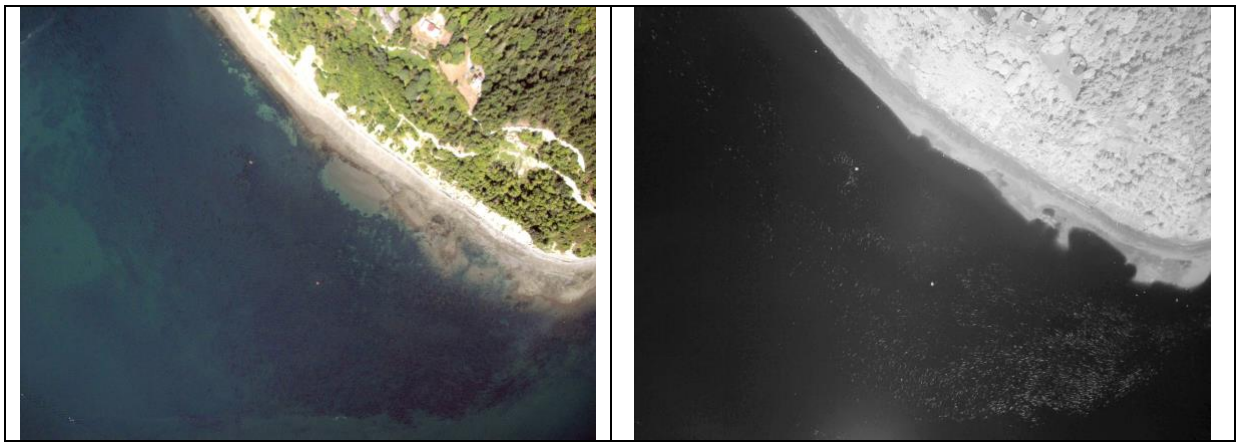
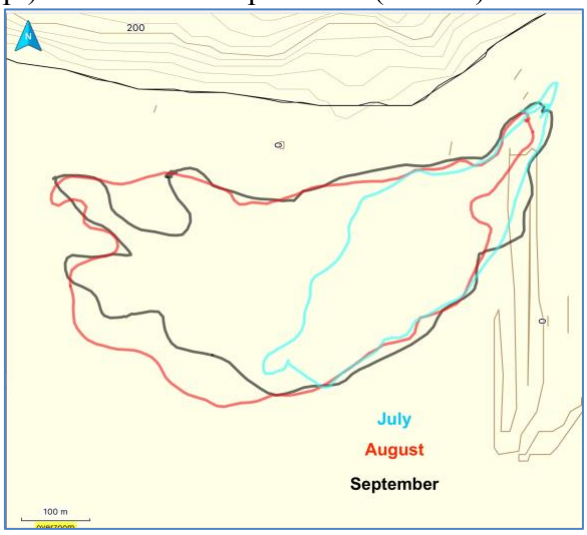


Figure 10. Possession Point bull kelp bed on August 31, 2018, contrasting appearance in visible light (left) with near infra-red (right). Note that nearly all of the kelp is visible at the surface in the near infra-red image. Photos by Gregg Ridder and Vernon Brisley.

A single monthly kayak survey was conducted in August 2017, when modest salinity (~30 ppt) and surface temperatures (~ 13°C) were observed. In 2018, monthly surveys from June through September were conducted. A survey conducted at the beginning of June (06/03/18) found only a few surface bulbs, while a late June survey (06/27/18) identified a bed, but equipment malfunction prevented perimeter track collection. Subsequent monthly surveys found consistently expanding kelp bed size (Figure 11).



The largest bed area was measured in September with a total of 144,405 m^2 or 35.14 acres (Appendix 1).

Figure 11. August 2017 perimeter of Possession Point kelp bed and area at a zero-foot tidal height in 2017.

IV. Aerial Imaging

Aerial imaging from a small private airplane was conducted primarily on August 19-20, 2017. The Island County shoreline was simultaneously photographed using a visible light (RGB) camera and a near infra-red (NIR) camera. Two types of photographs were collected: oblique images and orthogonal (straight down) photographs. A total of > 5,000 images were collected and georeferenced to the airplane's GPS data. These images were reviewed independently by two people using the same criteria for identifying images containing bull kelp. After independent assessment, the reviewers discussed and resolved discrepancies, and a map displaying shoreline with associated bull kelp beds was constructed (Figure 12).

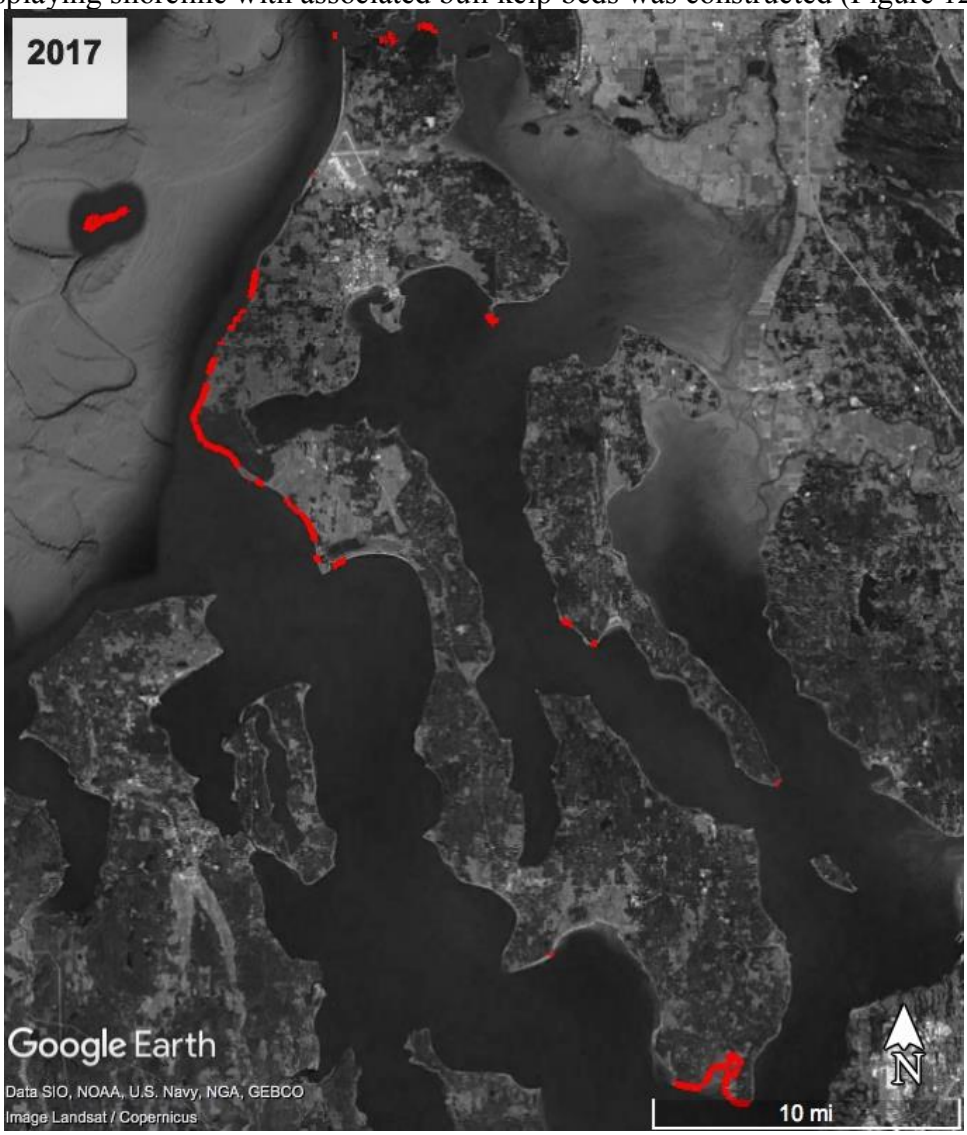


Figure 12. Map of Island County showing the amount of shoreline (red) with associated bull kelp beds.

The estimate of the amount of shoreline with associated bull kelp was **21.13 miles**, which is approximately **10% of Island County's shoreline**.

In 2018, aerial imaging (both visible light and near infrared) by Gregg Ridder was conducted using the same protocols as in 2017. Flights were conducted on August 31 and September 6, 2018.. The same methods used in 2017 for assessing the images will be applied to the 2018 images.

V. Field Thermometer Accuracy

Surface temperatures measured by inexpensive pool thermometers in the boat-based surveys indicated that temperatures were approaching the reported thermal limits for bull kelp. However, comparison of pool thermometers against a NIST-certified thermometer across a temperature range showed that some thermometers could vary as much as 2°C below the actual temperature (Figure 13A). When all pool thermometers used for the 2015 - 2017 surveys were compared to the NIST-certified thermometer across a temperature range, individual thermometers varied above and below the actual temperature, with some thermometers exhibiting less accuracy than others (Figure 13B). Whether these differences were due to difficulty in readings (thermometer scales were marked to the closest 2°C) or actual inaccuracy was not apparent.

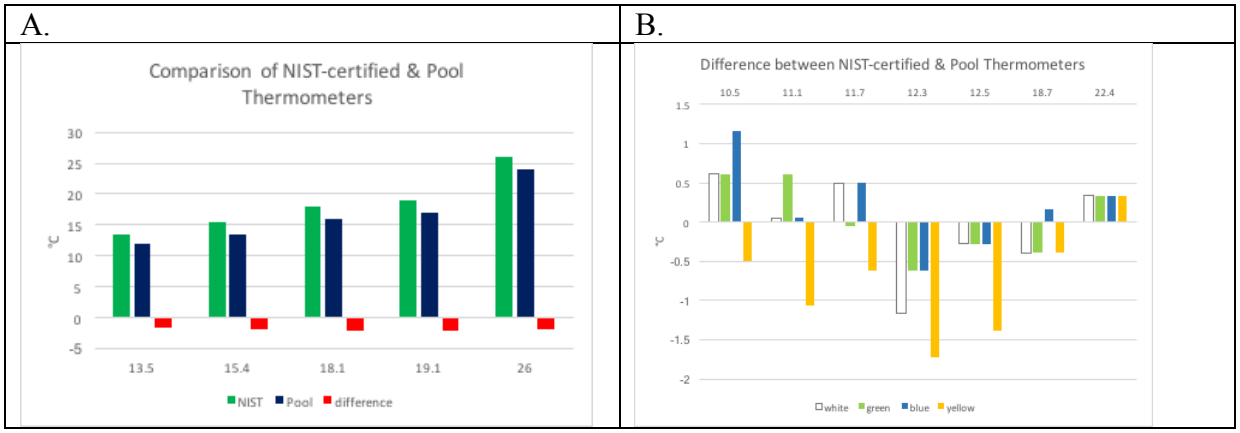


Figure 13. Mean deviation (n=3) of pool thermometers from a NIST-certified thermometer across a range of temperatures. (A) Example of an individual thermometer used in 2015 - 2017 surveys. (B) All pool thermometers used in bull surveys 2015 - 2017.

For the 2018 season, we purchased armored field thermometers widely used in ecological studies from a field equipment supplier (Ben Fields). We compared readings of the armored thermometers against a NIST-certified thermometer over a range of temperatures, & armored thermometer readings were estimated to the nearest 0.5 °C. Comparisons were made before (March 66, 2018) & after (March 9, 2019) the field season. Across the tested temperature range, all armored thermometers consistently produced readings below the NIST-certified thermometer (Figure 14). In brief, we found the field thermometers tended to underestimate the temperature from 0.5 - 1.6 °C. These observations suggest that uncalibrated thermometers should be compared to a high accuracy thermometer to establish their usefulness for surveys. Furthermore, it needs to be determined whether deviance from accurate readings can be used to make temperature corrections.

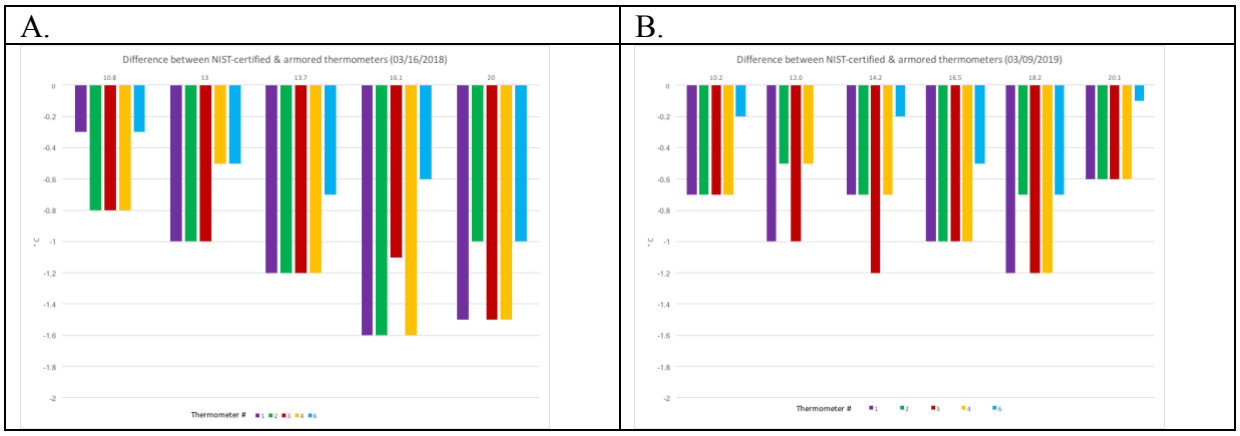


Figure 14. Mean deviation (n=3) of armored thermometers from a NIST-certified thermometer across a range of temperatures. (A) Differences from NIST-certified thermometer before 2018 field season. (B) Differences from NIST-certified thermometer after 2018 field season.

VI. Benthic Temperature Loggers

The lack of accuracy of the pool & armored thermometers as well as an interest in measuring bottom temperatures motivated exploring the option of using small temperature loggers, such as the Onset Hobo. Exploratory field deployment of Hobo loggers in 2017 revealed that these loggers required at least 5 minutes to equilibrate to a stable temperature, especially if the range of change > 10°C. In 2018, We explored using Hobo loggers to measure benthic temperatures by deploying them for at least 10 minutes in the bed. Figure 15 is an example of raw data from loggers deployed in August in the Ebey's Landing bed & the Polnell Point bed.

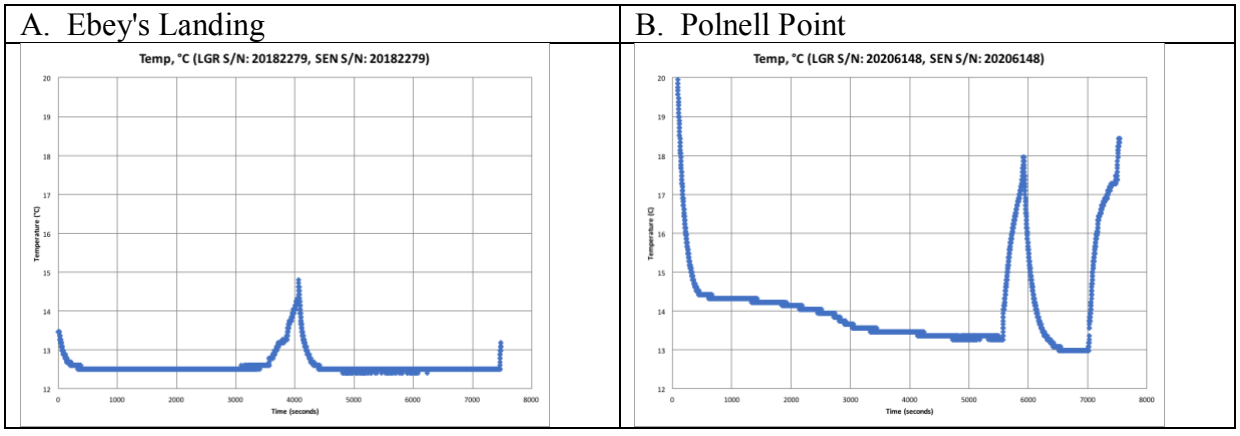


Figure 15. Raw temperature data plotted from Hobo loggers in beds at (A) Ebey's Landing & (B) Polnell Point.

Using these loggers, we collected benthic temperatures at points in the Ebey's Landing & Polnell Point beds. showing that temperatures at Polnell are consistently higher (Figures 16 & 17). Benthic temperatures at the Ebey's Landing declined from 13°C in July to 12.5°C in

August. Benthic temperatures at Polnell Point also declined, from a high of 17.3°C in July, to a range of 13.2 - 15.4°C in August, to a range of 13.6 - 13.6°C in September.

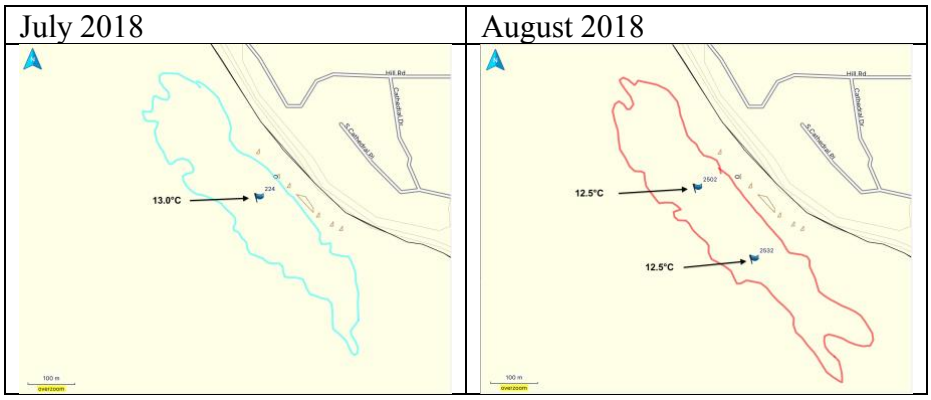


Figure 16. Benthic temperatures measured by Hobo loggers in Ebey's Landing bed in July & August 2018. Colored outlines delineate kelp bed margins.

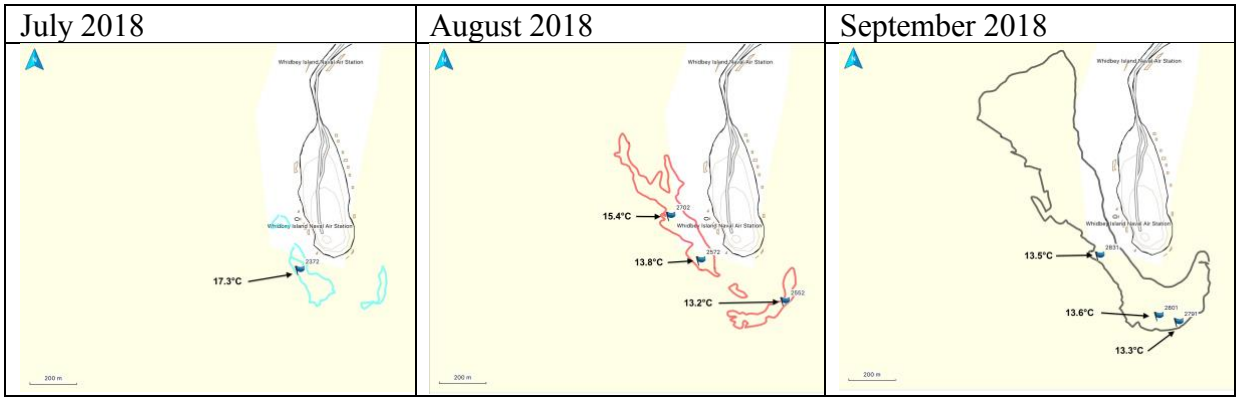


Figure 17. Benthic temperatures measured by Hobo loggers in Polnell Point bed in July, August, & September 2018. Colored outlines delineate kelp bed margins.

VII. Collect images of animals and plants within kelp beds

The cumulative reports (2015 - 2018) of animals & plants observed in beds are contained Appendix 2. In addition to noting organisms above & below the water during the boat-based surveys, 3 sets of observations were routinely made at each survey (reported in Appendix 1):

- Sori (presence or absence)
- Bryozoans on kelp (presence or absence; qualitative abundance)
- Kelp crab (presence or absence; qualitatvie abundance)

Kelp crab continued to be present in the Possession Point bed in relatively high abundance, an observation made in August 2017. In contrast, no kelp crab or only occasional individual kelp crab were observed in other beds.

VIII. References

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Appendix 1. Summary of bed areas, surface temperatures, and bed depths for all Island County kelp beds surveyed, 2015 through 2018. (See separate document.)

Appendix 2. Anecdotal observations of animals in bull kelp beds by site and month of survey, 2015 through 2018. (See separate document.)

Ben Ure Island 2016-2018

	2016 (0' tide height)				2017 (0' tide height)					2018 (0' tide height)	
	June	**July**	**mid August**	**late August**	**May**	**June**	**July**	**August**	**September**	**June**	**July**
bed area (m2)	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx
perimeter length (m)	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx
mean surface temp (°C)	12.2	11.9	13.3	12.2	8.9	9.6	11.7	12.4	11.1	11.9	12
minimum bed depth (m)	0.30	0.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.1	0.1
maximum bed depth (m)	4.42	3.96	5.79	5.88	3.81	3.81	---	5.79	6.10	2.3	4.4
mean bed depth (m)	2.36	2.21	2.89	2.94	1.90	1.90	---	2.90	3.05	1.6	2.3
minimum salinity (ppt)	---	---	---	---	---	---	---	---	---	---	---
maximum salinity (ppt)	---	---	---	---	---	---	---	---	---	---	---
mean salinity (ppt)	---	---	---	---	---	---	---	---	---	---	---
kelp crab abundance	---	---	---	---	---	---	---	---	---	absent	absent
sori abundance	---	---	---	---	---	---	---	---	---	present (abundant)	present (abundant)
bryozoan abundance	---	---	---	---	---	---	---	---	---	present (few)	present (few)

Notes "xx" indicates area & perimeter cannot be accurately determined because inner perimeter can not be tracked

Hoypus Point 2016-2018

	2016 (0' tide height)			2017 (0' tide height)		2018 (0' tide height)		
	July	**August**	**September**	**June**	**July**	**June**	**July**	**August**
bed area (m2)	16,315	15,008	13,722	5,496	14,585	---	19,624	730,287
perimeter length (m)	1,200	898	829	620	827	---	644	837
mean surface temp (°C)	14.2	14.4	12.6	9.42	9.63	12.3	12.8	12.5
minimum bed depth (m)	0.30	0.30	0.15	0.17	0	0.6	---	---
maximum bed depth (m)	4.42	4.27	4.72	3.96	3.35	5.5	---	---
mean bed depth (m)	2.36	2.28	8.00	1.98	1.68	2.6	---	---
minimum salinity (ppt)	---	---	---	---	---	---	---	---
maximum salinity (ppt)	---	---	---	---	---	---	---	---
mean salinity (ppt)	---	---	---	---	---	---	---	---

Polnell Point 2016-2018

	2016 (0' tide height)			2017 (0' tide height)				2018 (0' tide height)			
	July	**early August**	**late August**	**June**	**July**	**August**	**September**	**June**	**July**	**August**	**September**
bed area (m2)	19,117	71,187	145,003	1,471	5,321	29,340	110,908	0	24,687	70,348	300,040
perimeter length (m)	1,211	1,900	3,500	200	377	1585	2,877	0	1,800	3,400	4,200
mean surface temp (°C)	17.0	17.7	16.7	15.0	15.0	15.5	12.0	13.8	17.4	16.0	13.4
minimum bed depth (m)	2.74	1.83	3.96	0.61	0.61	---	1.83	1.2	0.8	3.0	2.4
maximum bed depth (m)	3.66	6.10	6.10	0.61	2.44	---	4.57	6.1	3.5	4.7	5.5
mean bed depth (m)	3.15	3.91	5.28	0.61	1.52	4.15	3.35	3.0	2.2	3.9	3.7
minimum salinity (ppt)	---	20.5	16.0	15.0	27.5	---	29.5	19.0	23.0	19.5	29.5
maximum salinity (ppt)	---	24.0	17.5	15.0	28.0	---	30.0	21.0	24.0	24.5	30.0
mean salinity (ppt)	---	22.2	16.8	15.0	27.8	15.8	29.6	20.4	23.8	21.3	29.9
kelp crab abundance	---	---	---	---	---	---	---	absent	absent	absent	absent
sori abundance	---	---	---	---	---	---	---	present	present (moderate)	present (numerous)	present (few)
bryozoan abundance	---	---	---	---	---	---	---	few	few	abundant (southern bed); moderate (western bed)	> 50% unaffected, but affected plants heavily infested

Notes											
				Parameters for only beds 1,2,3,& 6 included here, because could not measure beds 4 & 5 in September		Parameters for beds matching those reported for August.		only few bulbs present, near shore			

Lowell Point 2016-2017

	2016 (0' tide height)				2017 (0' tide height)		
	July	**August**	**September**	**September (2nd bed)**	**June**	**July**	**August**
bed area (m2)	51,543	71,187	72,775	1,652	0	15,995	55,631
perimeter length (m)	1,800	1,900	1,840	407.5	0	750	1,708
mean surface temp (°C)	17.0	17.7	14.4	14.4	15.5	14.0	14.4
minimum bed depth (m)	2.74	1.83	2.74	---	---	2.74	2.7
maximum bed depth (m)	4.57	6.10	7.01	---	---	8.23	5.9
mean bed depth (m)	3.66	3.91	4.67	---	---	5.09	4.13
minimum salinity (ppt)	26	---	---	---	---	---	---
maximum salinity (ppt)	27	---	---	---	---	---	---
mean salinity (ppt)	26.7	---	---	---	---	---	---

	2015 (0 - 0.5' tide height)				2015 (4 - 5' tide height)				2016 (0' tide height)			2017 (0' tide height)				2018 (0' tide height)			
	June	July	August	September	June	July	August	September	June	July	August	June	July	August	September	May	July	August	
bed area (m2)	38,384	59,151	74,302	79,992		48,419	56,004	64,460	73,946	82,492	76,781	56,802	81,554	84,713	91,759	18,662	74,876	86,136	
perimeter length (m)	1,288	1,448	1,931	2,092		1,287	1,609	1,770	1,600	1,900	1,700	1,400	1,500	1,500	2,240	1,100	1,800	2,000	
transect length (m)	148	483	483	644		483	644	483	---	---	---	---	---	---	---	---	---	---	---
bulb density (bulbs m-2)	1.95	1.50	1.55	2.02		0.78	0.64	0.87	---	---	---	---	---	---	---	---	---	---	---
mean surface temp (°C)	11.0	13.5	13.0	12.0		13.0	14.0	12.5	14.3	12.0	12.7	11.0	12.3	13.0	10.8	10.3	11.9	12.1	
minimum bed depth (m)	1.22	1.83	2.29	1.22		3.05	3.35	3.05	1.52	1.68	1.37	---	1.68	1.40	1.07	0.8	1.8	2.1	
maximum bed depth (m)	4.42	5.49	7.01	0.76		6.40	7.01	7.01	6.10	6.25	7.32	5.49	6.25	7.62	7.32	7.5	6.4	6.7	
mean bed depth (m)	2.92	3.58	4.42	4.11		4.50	5.27	4.83	3.96	4.17	4.32	---	3.76	4.20	4.14	5.5	4.2	4.0	
minimum salinity (ppt)	---	---	---	---		---	---	---	---	34.0	33.0	32.0	32.0	32.5	33.5	---	32.5	34.0	
maximum salinity (ppt)	---	---	---	---		---	---	---	---	34.0	34.0	33.0	33.0	33.0	34.0	---	33.5	34.5	
mean salinity (ppt)	---	---	---	---		---	---	---	---	34.0	33.5	32.5	32.2	32.8	33.8	---	33.0	34.2	
kelp crab abundance	---	---	---	---		---	---	---	---	---	---	---	---	---	---	absent	1 seen	absent	
sori abundance	---	---	---	---		---	---	---	---	---	---	---	---	---	---	present (abundant)	present (abundant)	present (abundant)	
bryozoan abundance	---	---	---	---		---	---	---	---	---	---	---	---	---	---	absent	few	few	

Possession Pt 2017-2018

	2017 (0' tide height)	2018 (0' tide height)				
	August	**early June**	**late June**	**July**	**August**	**September**
bed area (m2)	86,896	0	108,798	62,277	148,047	144,405
perimeter length (m)	1,500	0	1,600	1,400	2,100	2,300
mean surface temp (°C)	13.0	12.9	14.7	15.9	16.4	13.7
minimum bed depth (m)	3.05	0.80	1.80	0.90	1.80	2.13
maximum bed depth (m)	3.96	4.60	4.30	4.60	4.60	5.49
mean bed depth (m)	3.54	3.10	3.00	2.70	2.90	3.45
minimum salinity (ppt)	30.0	27.5	---	---	---	---
maximum salinity (ppt)	30.5	28.0	---	---	---	---
mean salinity (ppt)	30.1	27.7	---	---	---	---
kelp crab abundance	---	---	few	many (n = 50)	many (many ≥1 per stalk)	many (fewer than in July)
sori abundance	---	---	present (many)	present (many torn & empty)	present (new & torn)	present
bryozoan abundance	---	---	medium	high	high	high
notes		only few bulbs present, near shore				stalks fuzzy with growth

Appendix 2. Anecdotal observations in bull kelp beds by site and month of survey. Number observed, estimate of density, and/or estimate of distribution. "---" indicates no observation made.

Site	Month, Year	Birds	Mammals	Fish	Invertebrates
Ebey's Landing	June, 2015	Great blue heron fishing (2)	---	---	Dungeness crab zoea (high density throughout bed)
	July, 2015	Great blue heron fishing (1)	---	---	---
	August, 2015	Great blue heron fishing (2)	---	Unidentified small fish schools (few throughout bed)	---
	September, 2015	Heerman's gulls (>50); glaucous winged gulls (few); Western gulls (few)	---	Schools of small (<100 mm) salmonid-like fish; occasional jumping adult salmonids; perch-like fish (many throughout bed)	*Aurelia* jelly (few)
	June, 2016	Great blue heron fishing (1)	---	---	---
	July, 2016	Great blue heron fishing (2); rhinoceros auklet resting (1); bald eagle fishing (1); pigeon guillemot fishing (6)	river otter fishing & eating large sculpin (1)	Schools of small (4-6 cm) forage fish (high density throughout bed)	*Phacellophora* jellies (2); *Aurelia* jelly (1)
	August, 2016	Harlequin ducks fishing (8, females); bald eagle fishing (1); great blue heron fishing (1); pigeon guillemot fishing (1)	---	Schools of small (4-6 cm) forage fish (high density throughout bed); aggregates of shiner perch (multiple throughout bed)	*Phacellophora* jellies (2); bryozoans on fronds (numerous); large kelp crab (1)

	June, 2017	bald eagle (1); common loons fishing (2); great blue heron on kelp (1)	---	large school of forage fish in bed	---
	July, 2017	great blue heron on kelp (2); bald eagle (1); cormorant fishing (2)	---	many schools of small (≤5 cm) shiner perch	*Aurelia* sp. jellies (few)
	August, 2017	great blue heron fishing (3); Heermans gulls (6)	---	tubesnouts loafing in kelp blads (~24); many schools of herring ~ 25 mm TL; numerous schools of medium-large (6-10 cm TL) shiner perch	---
	September, 2017	Western grebe diving at margin (1); great blue heron on kelp (1); Heermans gulls (6); common loons (1 male, 1 female, 2 juveniles)at margin (4)	sea lion cruising margin (1)	NO forage fish schools	*Phacellophora* jellies (4); bryozoan colonies (*Membranipora* sp.) covering all submerged & exposed kelp parts
	May, 2018	< 6 Bonaparte's gulls (male & female)	---	few small schools (< 20 fish) of small fish (< 30 mm)	---
	July, 2018	bald eagle (hungting by skimming); 3 pair pigeon guillemots fishing within bed	harbor seal at bed perimeter (1)	multiple schools of forage fish; scattered shiner perch schools; school of tiny (< 20 mm) stickleback-like fish feed at surface)	---
	August, 2018	great blue heron hunting from kelp (1); 5-12 pigeon guillemots fishing within bed	harbor seal at bed perimeter (1)	numerous large schools of forage fish & perch	---
	June, 2016	---	---	---	---

Ben Ure Island (Cornet Bay)	July, 2016	Pigeon guillemot fishing (1); many other birds heard; great blue heron (several)	---	---	large Dungeness crab (1); *Nucella* sp. (numerouos throughout); *Sabellidae* sp (1 colony); *Evasteria* sp (1); *Pisaster ochraceus* (1); *Strongylocentrotus droebachiensis* (1); limpets (few); *Katharina tunicata* (1); unidentified invertebrate (see data sheet);
	August, 2016	gulls; loons	harbor seal (1)	---	*Strongylocentrotus droebachiensis*; *Cucumaria miniata* (several); *Phacellophora* jellies (many)
	September, 2016	gulls; pigeon guillemots (fly-bys);	harbor seal (1)	unidentified fish jumping	*Phacellophora* jellies (many)
	May, 2017	bald eagles	---	small fish splashing at surface at margin	*Pisaster ochraceus*; sea cucumber; *Strongylocentrotus droebachiensis* (14); chitons; *Katarina tunicata; Tonicella lineata*
	June, 2017	pigeon guillemots (fly-bys)	---	small fish splashing at surface	*Evasteria troschelii*; orange sea cucumbers; chitons (many)
	July, 2017	---	---	---	orange sea cucumbers
	August, 2017	Pigeon guillemots fishing (2-4)	---	---	---

	September, 2017	Great blue herons (3); pigeon guillemots; kingfisher	harbor seal (2)	---	orange sea cucumbers
	July, 2018	pigeon guillemots actively fishing throughout bed; bald eagle (1); great blue heron (1)	harbor seal (1)	slender silver fish jumping near outer bed border	numerous *Cucumaria miniata* above waterline
Hoypus Point	July, 2016	Pigeon guillemot in bed (1); many other birds above & from land	---	Unindentified fish (6-12" TL) jumping (3)	---
	August, 2016	Great blue heron on kelp (3)	harbor seal (1)	unidentified large fish jumping (1)	*Phacellophora* jellies (many)
	September, 2016	great blue herons on shore (3); gulls on kelp (many); loons (3)	---	unidentified large fish jumping (1)	*Phacellophora* jellies (many)
	June, 2017	---	---	---	---
	July, 2017	---	---	---	---
Polnell Point	July, 2016	Pigeon guillemot with gunnel-like fish & sculpins (2); great blue heron resting (8-10); bald eagle resting (1); apparent pigeon guillemot nests in cliffs	harbor seal on rock (1)	perch-like fish (few)	*Phacellophora* jellies (few)
	early August, 2016	Great blue heron resting (2); pigeon guillemot fishing (2)	harbor seals on rocks (3)	perch-like fish schools (numerous throughout bed)	*Phacellophora* jelly (1); bryozoans on fronds (numerous)
	late August, 2016	Great blue heron resting (1); harlequin ducks in bed (2, females); unidentified gulls (few)	harbor seals on rocks (3)	shiner perch schools (few)	*Phacellophora* jellies (numerous, 1-5' bells); bryozoans on fronds (numerous, ≤ 1.5" diameter)

	June, 2017	bald eagle (1); pigeon guillemots (2); great blue heron (2)	harbor seals on rocks (7)	shiner perch schools of ~20-30 fish	---
	July, 2017	pigeon guillemots (2); great blue heron (1); large osprey picked up large (~20-25 cm) perch from bed, then chased by bald eagle, dropped fish which was recovered by eagle	harbor seals on rocks (5 adults, 1 pup)	small (< 5 cm) shiner perch schools (few)	---
	August, 2017	pigeon guillemot fishing (5); bald eagle (1)	harbor seal in water (3)	small (≤ 2.5 cm) shiner perch schools (numerous)	*Phacellophora* jellies (12)
	September, 2017	bald eagle (1); great blue heron on rock (1)	---	---	*Phacellophora* jellies (3); bryozoan colonies (*Membranipora* sp.) on all submerged kelp parts
	June, 2018	bald eagle (1) water strike; great blue heron on shore (2); pigeon guillemot fishing (4)	harbor seals on rocks & in water (4)	schools of small (~ 3 cm) shiner perch	---
	July, 2018	great blue heron on rocks (2); medium-sized falcons around bluff & vocalizing (2); pigeon guillemot fishing (4-5)	harbor seals on rocks & in water (5)	few small perch-like fish	---
	August, 2018	great blue heron on rocks (2); rhinoceros auklet fishing (1); pigeon guillemot fishing (2)	harbor seals on rocks & in water (5)	multiple schools of perch-like fish	numerous ochre stars on larger rocks, 2-8" size

	September, 2018	great blue heron fishing from kelp (1); bald eagles on bluff (2)	harbor seals on rocks & in water (5)	---	---
Lowell Point (Camano Island State Park)	July, 2016	Pigeon guillemot fishing (6); Bonaparte gulls (numerous)	---	perch-like fish (numerous throughout bed)	Bryozoans on fronds (up to 40% of surface area); kelp crab on fronds (4-5); *Phacellophora* jellies (3)
	August, 2016	None observed	---	---	Bryozoans on fronds; *Phacellophora* jellies (4)
	June, 2017	---	---	---	---
	July, 2017				bryozoan colonies very small (*Membranipora* sp.)
	August, 2017	---	---	---	---
Possession Point	August, 2017	Caspian terns diving (8)	harbor seal (2) & sea lion (1) on rock in bed	numerous large forage fish schools in bed; multiple large (~ 12") jumpers, possibly salmon; multiple small (<2") shiner perch schools	~20% of kelp have ≥1 kelp crab (numerous bulbs eaten away); live amphipods on water surface
	June, 2018	bald eagle water strike (1); great blue heron on shore (4); few auklet-like birds; pigeon guillemot (2)	sea lion in water (1); harbor seals on rocks & in water (6)	school of smal (~ 3 cm) shiner perch; few smaller schools of tiny (< 2 cm) fish	red rock crab (1)
	July, 2018	---	---	---	many kelp crab
	August, 2018	---	harbor seals (2)	schools of 2-3" fish; starry flounder (2)	many kelp crab
	September, 2018	---	---	starry founder (1)	many kelp crab