NATURAL RESOURCES

Kelp forest monitoring with volunteer kayak surveys:

Data synthesis and recommendations for the MRC Volunteer Kelp Monitoring Program

Final report to the Northwest Straits Commission

IAA 93-102466

June 30, 2023

WASHINGTON STATE DEPT OF NATURAL RESOURCES

Northwest Straits COMMISSION
partners in marine conservation

The Nearshore Habitat Program is part of the Washington State Department of Natural Resources – Aquatic Resources Division, and supports the agency's work to ensure environmental protection of Washington's state-owned aquatic lands (https://www.dnr.wa.gov/programs-and-services/aquatics/aquatic-science/nearshore-habitat-program).

The Nearshore Habitat Program is also a component of the Puget Sound Ecosystem Monitoring Program (PSEMP) (https://www.psp.wa.gov/PSEMP-overview.php).

Cover photo: North Beach bull kelp bed. Photo Credit: Julia Ledbetter.

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Contents

Executive Summary

Kelp is a type of large marine algae that occurs in many nearshore systems and provides important habitat for myriad species. In response to mounting concerns about floating kelp losses in Puget Sound, diverse communities have called for greater understanding of kelp status and trends. This report summarizes a collaboration between the Northwest Straits Commission (NWSC), local Marine Resources Committees (MRCs), and the Washington State Department of Natural Resources (DNR) to address information gaps through synthesis of volunteer-collected floating kelp monitoring data.

Since 2015, MRC volunteers from seven counties have surveyed floating kelp beds via kayak to better understand this component of the marine ecosystem. The MRC Kayak-based Floating Kelp Canopy Monitoring Program increases community engagement and collects data that can enhance understanding of trends in canopy-forming kelp in the Puget Sound. However, data analysis, methodological enhancement and reporting have been limited thus far.

The overall goal of this project was to ensure the volunteer monitoring data is "both useful and used" in kelp conservation. This report addresses three related project objectives:

(1) synthesize the MRC kelp data for inclusion in the Puget Sound Partnership's Vital Signs, as part of the Floating Kelp Bed Area Indicator,
(2) create broadly accessible communications products, including the development of an ArcGIS StoryMap to highlight the data and showcase the volunteer effort, and
(3) provide recommendations to improve future data collection.

Key results:

1. Integrated MRC kelp data from 18 sites into the Floating Kelp Bed Area Indicator within the Puget Sound Partnership's Beaches and Marine Vegetation Vital Sign. In future years, these data will continue to be integrated into the Indicator through the WA Kelp Forest Alliance, a diverse alliance of organizations that cooperatively monitor floating kelp.
    - A detailed review of existing MRC kelp data identified 18 sites (out of 31) for inclusion in the Floating Kelp Bed Area Indicator. Site selection criteria included data completeness, reliability, and time series spanning at least five years.
    - A systematic procedure was developed for integrating MRC kelp data into the Indicator.
    - A trend analysis at each of the 18 selected sites revealed:
        - 13 sites had no detectable trend in kelp bed area,
        - 2 sites had a total loss of kelp over the data record (Meadowdale and Mukilteo),
        - 1 site had declining kelp bed area, and
        - 2 sites had increasing kelp bed area.

- In future years, NW Straits will lead data assessment work. DNR will continue to integrate results into the indicator and collaboratively review data and trend assessments with NW Straits.
- The survey protocols and indicator integration workflow provide a demonstration case for other groups interested in monitoring kelp via kayaks for the Indicator.

2. Produced multiple communications products that highlight the MRC kelp data, including a series of Floating Kelp Bed Area Indicator products and an ArcGIS StoryMap.
   - The MRC data supports the Washington State Floating Kelp Indicator program, which synthesizes multiple datasets, reports overall findings, then drills down into greater detail. Customized summaries of MRC sites emphasize the volunteer program. Indicator products include:
     - Interactive map
     - Statewide summary report
     - Monitoring Program Design and protocols
     - Puget Sound Partnership PS Info web page
   - DNR and NW Straits jointly developed an ArcGIS StoryMap that highlights volunteer efforts and communicates findings. NW Straits is leading further development and maintenance of the StoryMap.

3. Recommended enhancements to the current MRC kelp monitoring program as well as ideas for potential program expansion. DNR Nearshore Habitat Program scientists recommend dedicating a full-time staff position to adequately support data quality assessment, interpretation, and distribution.
   DNR recommends six key priorities for future data collection and analysis (with most immediate priorities in **bold**).
   - **Define a shoreline segment and record survey endpoints for each site** that identifies the area being surveyed and record the alongshore distance that volunteers kayak each survey.
   - **Set constraints on survey field conditions**. Data analysis, survey notes, and interviews all identified challenges associated with tides, currents, and a variety of environmental conditions. Standardizing these criteria as much as possible when planning survey days and times and identifying site-specific survey windows will help control these sources of variability.
   - **Improve consistency in applying protocol's survey distance threshold** to delineate a kelp perimeter. Expanded training will help minimize the challenge of protocol interpretation in the field.
   - Expand monitoring to additional sites as volunteer interest and capacity allows.
   - Co-locate additional monitoring sites to the greatest extent practical with other groups monitoring kelp in the region (e.g., Puget Sound Restoration Fund, DNR, Reef Check Foundation, Samish Indian Nation).

- Consider protocol improvements while maintaining backwards compatibility. When considering changes or additions to the survey protocol, prioritize consistency if the goal is to detect changes over time.

This project focused primarily on integration of the MRC kelp data into the Floating Kelp Bed Area Indicator. However, the MRC Volunteer Kayak-based Floating Kelp Canopy Monitoring Program does not need to limit itself to the confines of the relatively narrowly defined indicator. The NW Straits and MRCs can consider many potential expansions to meet their organizational priorities, including:

- Analyze and interpret other existing data streams in the program (e.g., depth, temperature, species present).
- Monitor environmental conditions, such as temperature and land use to better understand factors driving floating kelp trends.
- Monitor usage of kelp beds by fish, birds, invertebrates, and mammals. Many volunteers value the animals that use kelp beds.
- Expand monitoring methods to include Uncrewed Aerial Systems (UAS), underwater imagery, and other techniques.
- Expand species monitored beyond floating kelp.
- Extend the time span of long-term trends through integrating historical data. Many of the counties with MRCs have substantial information gaps, due to limited inclusion of historical data. Through identifying diverse information sources, volunteers could fill gaps and extend temporal baselines.

1 Introduction

1.1 Kelp in Puget Sound

In Puget Sound there are more than 20 species of kelp, large brown algae in the order Laminariales (Mumford 2007). While most species are understory kelps (i.e., kelp that do not reach the surface of the water), two species of floating kelp, bull kelp (*Nereocystis luetkeana*) and giant kelp (*Macrocystis pyrifera*) form large buoyant canopies that float on the water surface. Floating kelp forests occur along 11% of Washington's shoreline (Nearshore Habitat Program 2001). Bull kelp is the most widespread species. Floating kelp beds provide vital habitats for many important species and are a critical part of the Puget Sound food web. Many species with socioeconomic value rely on kelp beds for refuge and foraging grounds, including salmon, rockfish, forage fish, and orcas. Kelp forests also provide important ecosystem services such as primary production, nutrient cycling, and wave attenuation (Smale et al. 2013). Kelp growth and persistence can be affected by changes in environmental conditions including water temperature, pH, water clarity, and nutrient availability (Hollarsmith et al. 2020, Krumhansl et al. 2016, Schiel and Foster 2015).

Kelp beds exhibit high natural variability, and kelp abundance varies throughout the Salish Sea. However, there has been a substantial loss in bull kelp beds in some inner basins of Puget Sound compared to historical distributions (Berry et al. 2021). The predicted impacts of climate change and population growth pose a serious threat to kelp persistence (Rogers-Bennett and Catton 2019, Wernberg et al. 2016). In 2020, a diverse group of partners including the Northwest Straits Initiative, National Oceanic and Atmospheric Administration, Washington State Department of Natural Resources (DNR), and others published the Puget Sound Kelp Conservation and Recovery Plan to provide a research and management framework for coordinated actions to advance knowledge of kelp forest trends and to strengthen conservation and restoration efforts (Calloway et al. 2020).

1.2 DNR and Northwest Straits Commission

This report describes a collaborative project between two agencies with missions to advance understanding of floating kelp in Washington State. DNR is the steward to more than 2.6 million acres of state-owned aquatic lands and works to protect the habitat and provide public access for current and future Washington State residents. As part of this responsibility, DNR's Nearshore Habitat Program monitors the health of nearshore marine vegetation and other indicators of habitat health along Puget Sound's shorelines.

The Northwest Straits Initiative (NW Straits) is a community-led collaboration working to protect and restore the marine environment of northwest Washington. The NW Straits carries out their work through the Marine Resources Committees (MRCs), the Northwest Straits Commission, and the Northwest Straits Foundation. As part of its regional actions, the Northwest Straits Commission coordinates volunteer-based kelp canopy monitoring with MRCs in counties in the northwest straits region. This citizen-science monitoring program increases community engagement and collects data that can be used to improve understanding of trends in canopy-forming kelp across the region.

1.3 Community Science and Monitoring by Kayak

Community science has been broadly defined as participation by the public in scientific research, typically under the direction of, or collaboration with, scientific researchers or organizations (Earp and Liconti 2020). While important fine-scale distinctions exist between the terms community science, citizen science, and other grassroots efforts (Lin Hunter et al. 2023), this report uses the term community science to generally encompass all of these efforts. Community science projects can increase environmental awareness (Cigliano et al. 2015) and engage community members to support and participate in local conservation efforts, furthering outreach efforts. In addition to the benefits of community science, challenges exist. While community science projects aim to have the same data quality standards as professional scientific research, they can encounter tradeoffs between data quality and quantity, differences in participant skills, and protocol standardization (Robertson et al. 2010). These challenges can be mitigated by simplified tasks, detailed protocols, and targeted trainings (Thiel et al. 2014).

In marine systems, community science is often concentrated in easily accessible coastal habitats including sandy beaches, coral reefs, and seagrass beds (Thiel et al. 2014). While there are challenges with community science projects (e.g., participant motivation and data concerns; Earp and Liconti 2020), a review of 227 marine community science projects by Thiel et al. (2014) concluded that community science can produce invaluable contributions to the field of marine science as well as foster marine stewardship.

The surface canopies of floating kelp beds represent a relatively tractable habitat for conducting community science. Diverse survey methods exist, including satellites, fixed-wing aircraft, Uncrewed Aerial Systems (UAS), small boats, and underwater surveys with SCUBA (Cavanaugh et al. 2021, Thompson 2021). In the Salish Sea, numerous organizations monitor kelp beds by kayak (DNR Nearshore Habitat Program, Samish Indian Nation, Mayne Island Conservancy, NW Straits), and some involve community scientists in these efforts. The Mayne Island Conservancy has coordinated a volunteer kayak-based monitoring program in the Southern Gulf Islands, British Columbia, at 17 sites (as of 2022) for 13 years (Underhill 2022).

This report focuses on the MRC Kayak-based Floating Kelp Monitoring Program (hereafter "MRC kelp monitoring program"), a community-science project modeled after the Mayne Island Kelp Monitoring Program and coordinated by NW Straits. Since 2015, the MRC kelp

monitoring program has trained volunteers to map local kelp beds by kayak using a handheld GPS.

1.4 Study area

The MRC kelp monitoring program deploys volunteer surveyors (hereafter "volunteers") in seven northern Washington counties (Snohomish, Island, Skagit, Whatcom, San Juan, Jefferson, and Clallam counties) (Figure 1). These counties span distinct geographic regions of the Salish Sea including the Strait of Juan de Fuca, the San Juan Islands, North Puget Sound, the Saratoga-Whidbey basin, and Central Puget Sound. The MRC kelp monitoring program has surveyed a total of 44 kelp beds at 31 distinct sites throughout all seven MRC counties. Since program inception, some monitoring sites have been dropped and new ones have been added. During the 2021 monitoring season, there were 22 sites in six counties (no sites are currently surveyed in San Juan County).

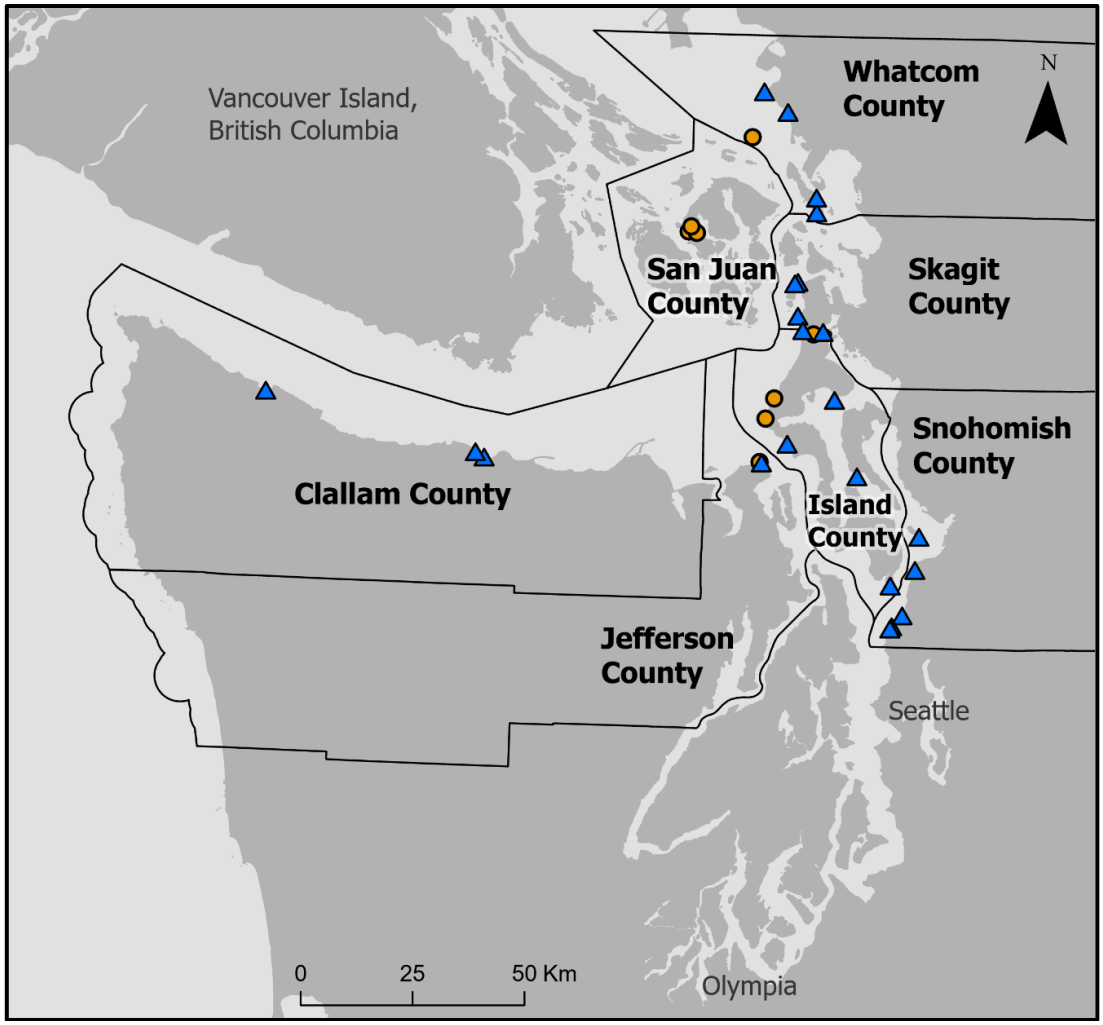

Figure 1. Marine Resources Committees (MRCs) kayak-based floating kelp monitoring sites in seven northern counties in Puget Sound, WA. Blue triangles represent sites surveyed in 2021 and orange circles represent sites no longer surveyed.

Project Objectives

NW Straits currently processes and publishes the MRC kelp monitoring data on the SoundIQ web map, which MRCs then use to inform county officials. While interactive web-based maps can be informative, additional analysis and promotion of the regional dataset is needed to maximize its usage. Topics of further analysis and interpretation to consider include local bed characteristics, regional patterns, and change over time. The broad goal of this collaborative project was to ensure the MRC kelp monitoring data is "both useful and used". This goal was divided into three distinct objectives:

1. Synthesize the MRC kelp monitoring program data for inclusion in the Puget Sound Partnership's Beaches and Marine Vegetation Vital Sign, as part of the Floating Kelp Bed Area Indicator,

2. Create broadly accessible communications products, including the development of an ArcGIS StoryMap to highlight the data and showcase the volunteer effort, and

3. Provide recommendations to improve future data collection.

Each of the above objectives is addressed in a separate section of the report.

2 Indicator Inclusion

2.1 Introduction

The Puget Sound Partnership (PSP) is a Washington State agency that aims to restore and conserve Puget Sound with an ecosystem-based management approach. In 2011, PSP introduced the Puget Sound Vital Signs to track Puget Sound ecosystem health and progress toward recovery goals. In 2020, the Vital Signs program identified new indicators for inclusion, including Floating Kelp Bed Area, as part of the set of indicators making up the Beaches and Marine Vegetation Vital Sign.

Between Fall 2021 and May 2023, a diverse alliance of organizations, the WA Kelp Forest Alliance, created the Floating Kelp Bed Area Indicator (hereafter "Indicator"). The Indicator uses long-term kelp monitoring data to assess kelp status and trends throughout Washington State (see Berry et al. 2023) and is populated by the WA Kelp Forest Alliance. More information can be found on the FloatingKelpWA website and PSP's Vital Sign website. The MRC kelp monitoring data was one of the datasets identified for inclusion. This project developed and implemented methods to incorporate the MRC kelp data into the Indicator (described below).

2.2 Methods

MRC kelp monitoring sites were evaluated individually for inclusion in the Indicator. The primary factors considered were (1) number of years surveyed, (2) consistency among surveys in data collection methods, and (3) the spatial extent overlap of multiyear surveys.

2.2.1 Data Review and Processing

DNR reviewed the MRC kelp dataset and identified 18 sites with at least five years of data to assess for inclusion in the Indicator. Volunteers that surveyed the floating kelp bed area at each of the 18 sites were interviewed to gain insights into site and survey conditions, methods, and uncertainties around the data. DNR worked with volunteers to delineate a "Indicator survey extent" for each site, defined as the area that had been consistently surveyed for floating kelp each year. Defining Indicator survey extents was important to determine which surveys could be directly compared and what surveys needed to be cropped or excluded from multiyear comparisons (see Appendix 3 for more details). At some sites, multiple kelp beds were incorporated in the same Indicator survey extent (e.g., Mukilteo) and at one site, multiple kelp beds were split into separate Indicator survey extents (Edmonds North and

Edmonds Dive Park). Table 1 in Appendix 3 presents the MRC kelp bed name and associated site name.

DNR designed a repeatable procedure and workflow to refine, restructure, and append suitable MRC kelp data to the Indicator dataset. This workflow is documented in Appendix 3 and in the MRC Kayak Dataset Description referenced in the Monitoring Program Design and Data Assessment Protocols (Berry et al. 2023). In summary, the data flow includes:

1. Uploading of kayak-collected kelp perimeters and field datasheets by volunteers to KoBoToolbox, an online data collection tool utilized by NW Straits.
2. NW Straits downloads data from KoBoToolbox to process and compile into a single database (NWSC database) that is used to inform the SoundIQ web map (Figure 2). The NWSC Database contains all years of MRC survey data, associated field notes, and any additional data.
3. The NWSC database is then passed to DNR where it is refined and restructured to create a DNR 'working' database which consists of the entire MRC kelp dataset as well as additional descriptive attributes to streamline analysis.
4. The Indicator Database is then derived from the DNR working database and includes a subset of the MRC kelp dataset to be incorporated into the Indicator (Appendix 3, MRC Kayak Dataset Description).

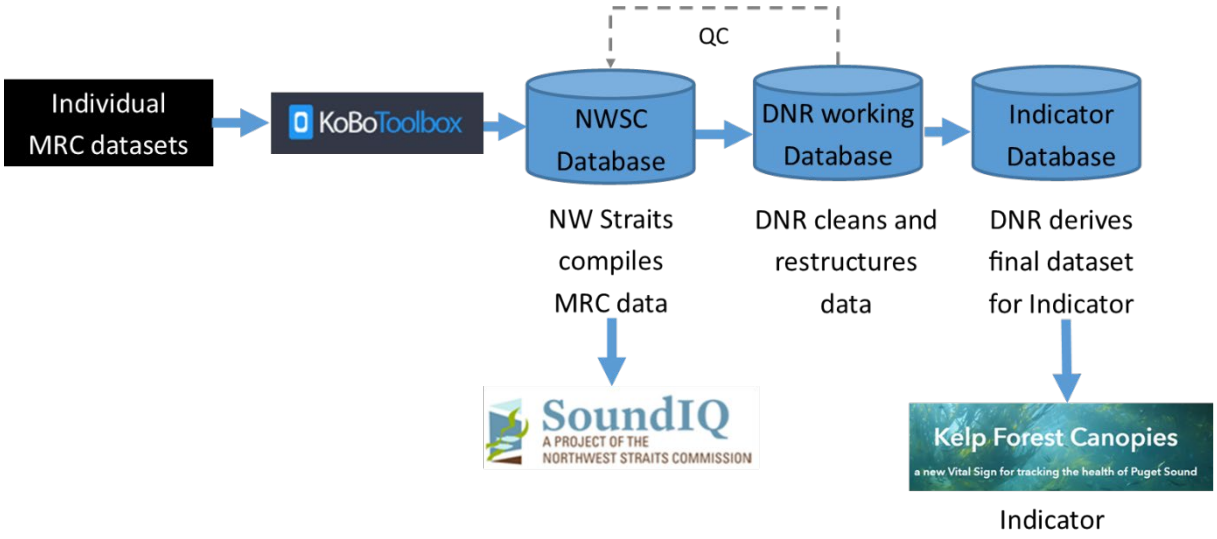

Figure 2. Simple flow chart of MRC kelp datasets from field collection to Indicator database (more details can be found in Appendix 3).

The subset of the MRC kelp dataset within the Indicator Database contains all the kelp bed perimeters collected at each of the 18 Indicator sites. To accurately compare kelp bed area over time, the perimeters were clipped to the Indicator surveys extents (described above). This created a feature class consisting of the perimeters within the Indicator survey extent polygons that are suitable for analysis (more details in Appendix 3). The kelp bed area data was then

summarized to prepare it for analysis. First, for sites that had multiple beds surveyed at a site on a single date, the beds were summed for each date (e.g., Mukilteo, Edmonds). Next, if there were replicate surveys of a kelp bed on one survey date, the replicates were averaged to get one bed area per survey date. Finally, the data was summarized to select the annual maximum bed area for each site, which was used for all analyses.

2.2.2 Site Classification

Through data analysis and interviewing volunteers, long-term and recent trend classifications were assigned for each site. Linear regressions of annual maximum bed area (analyzed with data through 2021) assigned each site a trend (*increasing*, *no trend*, *decreasing*, *total loss*, and *limited data*) (Berry et al. 2023). If the bed area of most recent year was zero, the site was assigned the classification of *total loss*. If the bed area was greater than zero, the trend was determined by the p-value and slope of the linear regression. A positive, statistically significant ($p < 0.05$) change in area over time was classified as *increasing* while a negative, statistically significant ($p < 0.05$) change in area over time was classified as *decreasing*. Change in area over time that was not statistically significant ($p > 0.05$) was classified as no *trend*.

DNR reviewed the regression-determined trend designations along with visual assessment of site maps and graphical data, as well as a series of conditional questions for trend confirmation below:

- If changes were observed, was there a discernable spatial pattern? Changes in bed area may be driven by changes in localized areas of the bed.
- What is the signal-to-noise ratio? This is a multi-year assessment factor; it evaluates if the change over time is substantially greater than the sampling "noise".
- How consistent were the environmental conditions among years? Volunteers occasionally make notes about challenging survey conditions or sudden changes in weather conditions that impact kelp detection.
- How consistently was the MRC protocol followed? Volunteer interviews showed confusion in some cases with interpreting the survey protocol, which could affect the data. The volunteer using the GPS during a survey may change from year to year and differences in protocol interpretation introduces variation into the data.

Based on the review, DNR either confirmed or overrode the regression-based trends assignments and final trends were assigned for the recent data record (past five years) and the entire data record (for more details on classification methods see in Berry et al. 2023).

2.3 Results

2.3.1 Indicator Site Inclusion

Based on the initial review of the MRC kelp data, DNR created and incorporated 18 sites into the Indicator dataset (Table 1). Four sites (out of the 31 total sites) with either only one year

of data or logistical constraints and no plans for additional surveys were excluded from the Indicator dataset. Eight sites are pending inclusion in the Indicator dataset because there is either less than five years of data or they have no recent data (site is no longer surveyed). Appendix 4 of this report contains the Indicator survey extents delineated for the 18 MRC sites that were incorporated into the Indicator, along with the rationale for pending and excluded sites.

Table 1. MRC kayak survey sites, including the years surveyed and if the site was included in the Floating Kelp Bed Area Indicator (Status). Sites are color-coded by the number of years surveyed.

Site Name	2015	2016	2017	2018	2019	2020	2021	Status
Ebey's Landing	x	x	x	x	x	x	x	Included
Edmonds North	x	x	x	x	x	x	x	Included
Meadowdale	x	x	x	x	x	x	x	Included
Mukilteo	x	x	x	x	x	x	x	Included
North Beach Main	x	x	x	x	x	x	x	Included
Polnell Point		x	x	x	x	x	x	Included
Lummi SW		x	x	x	x	x	x	Included
Coffin Rocks		x	x	x	x	x	x	Included
Freshwater Bay		x	x	x	x	x	x	Included
Observatory Point		x	x	x	x	x	x	Included
Biz Point			x	x	x	x	x	Included
Cherry Point			x	x	x	x	x	Included
Edmonds-Dive Park			x	x	x	x	x	Included
Hat Island			x	x	x	x	x	Included
Possession Point			x	x	x	x	x	Included
Shannon Point-East			x	x	x	x	x	Included
Shannon Point-West			x	x	x	x	x	Included
Clallam Bay			x	x	x	x	x	Included
Aiston Preserve				x	x	x	x	Pending
Camano Island		x	x			x	x	Pending
Hoypus Point		x	x	x			x	Pending
Point Whitehorn		x			x	x	x	Pending
Alden Bank				x	x	x		Excluded
Ben Ure		x	x	x				Pending
Pole Pass	x	x	x					Pending
North Beach West	x				x			Excluded
Fawn Island		x	x					Pending
Reef Island		x	x					Pending
Freshwater Bay 3				x				Excluded
Hastie Lake	x							Excluded
Libbey Beach	x							Excluded

Years of data:	7 years	6 years	5 years	4 years	3 years	2 years	1 year

2.3.2 Trend classifications and data observations

DNR determined recent and long-term trends in kelp bed area for each site using linear regression, along with an assessment of survey line maps, graphs of the maximum bed area

per year, survey notes, and volunteer interviews. Maps and graphs of each MRC site included in the Indicator can be found in Appendix 1, along with site summaries. Of the 18 MRC sites incorporated into the Indicator, the trend analysis classified two sites as *increasing*, one site as *decreasing*, two sites as *total loss*, and 13 sites as *no trend* (Table 2, Figure 3). Most sites exhibit substantial year to year variation in kelp bed area (Appendix 1), which resulted in many sites classified as *no trend*. At two sites, Ebey's Landing and Possession Point, volunteers observed that mapped kelp beds expanded and merged with an adjacent bed, resulting in an *increasing* trend classification (Appendix 1, Figures 5 and 16, respectively). At Meadowdale and Mukilteo, the two sites classified as *total loss*, since floating kelp was absent in 2020 and 2021 (Appendix 1, Figures 11 and 12, respectively). Continued annual surveys will determine if these losses are permanent. Freshwater Bay was the only MRC site classified as *decreasing*, which contracted on the eastern side in recent years (Appendix 1, Figure 8).

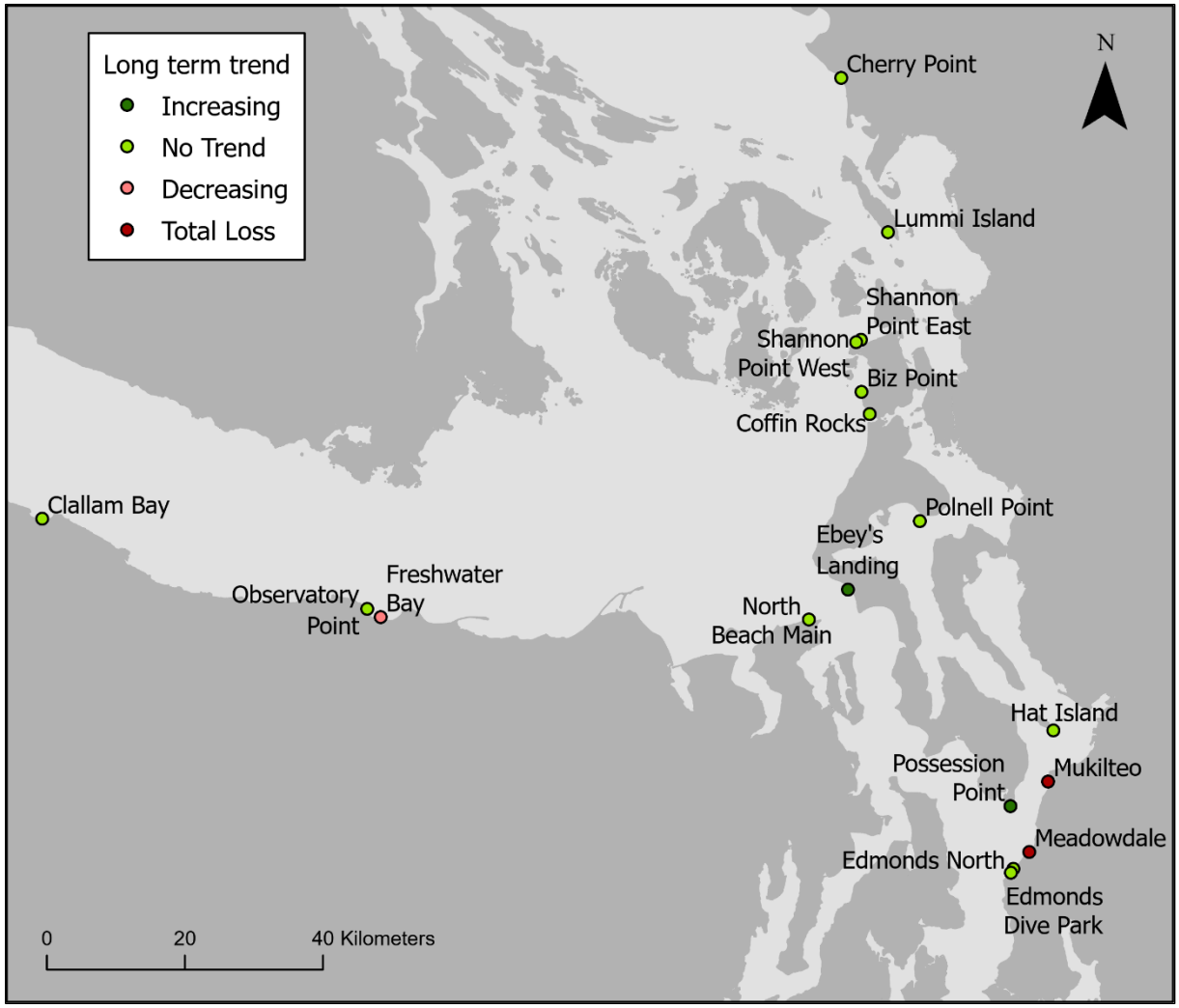

Figure 3. Long term trend classifications for each site of the 18 MRC sites included in the Floating Kelp Bed Area Indicator.

The Edmonds North site was classified as *no trend* but was a candidate to be classified as *declining*. The site shows a large decline in bed area (2015-2018) and then an oscillation around a lower abundance (2018-2021). Visual inspection of survey perimeters shows both the shallow and deep kelp beds have contracted on the north and south ends of the beds (Figure 4). A linear regression of the entire data record showed no significant difference between years ($p = 0.22$), which led to the *no trend* classification. While the site was classified as *no trend* in 2021, there is rationale for changing the classification to *declining*. It would be good to revisit this site classification when the 2022 data is integrated into the Indicator.

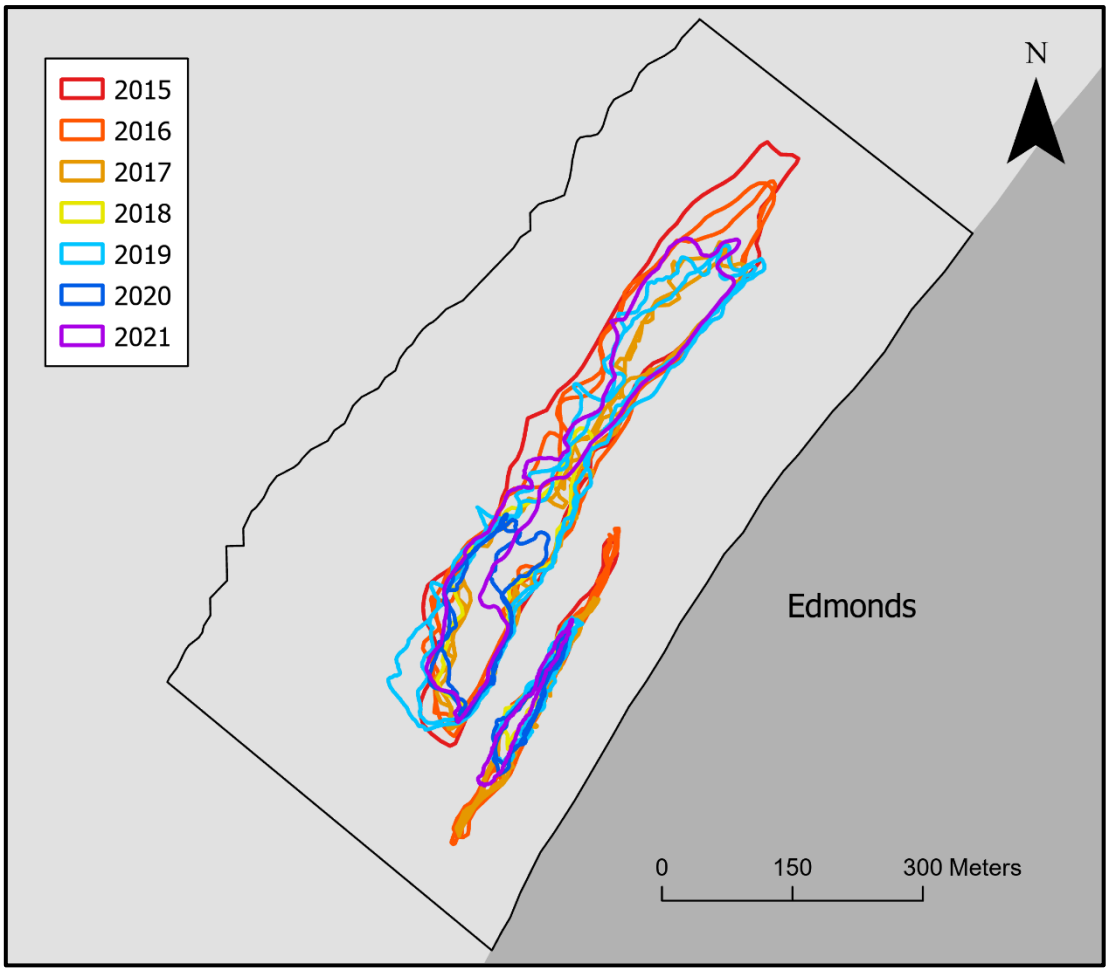

Figure 4. Annual maximum kelp bed perimeters at Edmonds North, Snohomish County, WA.

Table 2 displays the recent and long-term trend classifications for each MRC site in the Indicator, including regression slopes and p-values and the length of the data record. Classifications may change with additional data, analysis, and interpretation of field observations. With short data records (five to seven years), the recent and long-term trends do not differ. It is important to note that the trend results for the MRC sites span a limited

number of years, and that continued data collection will further enrich our understanding of kelp trends.

Data collected in 2022 is in review and will be added to the Indicator dataset for the next update. In future years, NW Straits will lead the assessment of the MRC kelp data and DNR will continue to integrate those results into the Indicator.

Table 2. Assessments of Floating Kelp Bed Area at MRC sites that were incorporated into the Indicator through 2021. Bold p-values indicate significance.

Indicator Site Name	Number of years surveyed	Long-term trend			Recent trend			Mean bed area in years when kelp was present (ha) (min-max)	% difference between 2021 bed area and long-term mean
		Classification	slope	p-value	Classification	slope	p-value		
Biz Point	5	No trend	0.040	0.96	No trend	0.040	0.96	0.26 (0.2-0.4 ha)	+37%
Cherry Point	5	No trend	-0.904	0.26	No trend	-0.904	0.30	6.90 (3.5-9.3 ha)	-50%
Clallam Bay	5	No trend	-1.026	0.21	No trend	-1.026	0.24	7.66 (5.3-10.2 ha)	-19%
Coffin Rocks	6	No trend	0.040	0.9	No trend	0.042	0.96	0.49 (0.4-0.7 ha)	+40%
Ebey's Landing	7	Increasing	1.334	**0.007**	Increasing [a]	1.623	**0.07**	10.80 (7.4-14.3 ha)	+30%
Edmonds Dive Park	5	No trend	-0.006	0.99	No trend	-0.006	0.99	0.21 (0.1-0.4 ha)	-39%
Edmonds North	7	No trend	-0.594	0.22	No trend	0.003	0.99	3.69 (1.4-6.7 ha)	-12%
Freshwater Bay	6	Decreasing	-4.956	**<0.001**	Decreasing	-4.794	**<0.001**	55.35 (44.3-68.7 ha)	-11%
Hat Island	5	No trend	-0.697	0.39	No trend	-0.697	0.43	11.56 (6.2-16.3 ha)	-5%
Lummi SW	6	No trend	-0.016	0.98	No trend	-0.016	0.99	1.03 (0.8-1.2 ha)	+15%
Meadowdale	7	Total loss	-0.125	0.80	Total loss	-0.020	0.98	0.49 (0.8-0.1 ha)	-100%

Indicator Site Name	Number of years surveyed	Long-term trend			Recent trend			Mean bed area in years when kelp was present (ha) (min-max)	% difference between 2021 bed area and long-term mean
		Classification	slope	p-value	Classification	slope	p-value		
Mukilteo	7	Total loss	-0.271	0.57	Total loss	-0.019	0.98	0.71 (2.1-0.06 ha)	-100%
North Beach Main	7	No trend	0.093	0.88	No trend	0.780	0.37	6.88 (3.8-10.3 ha)	+49%
Observatory Point	6	No trend	-0.004	0.99	No trend	-0.034	0.97	0.38 (0.3-0.6 ha)	-2%
Polnell Point	6	No trend	0.134	0.83	No trend	-0.351	0.69	16.82 (11.1-25.9 ha)	-12%
Possession Point	5	Increasing	2.544	**0.002**	Increasing	2.544	**0.005**	16.89 (8.7-22.4 ha)	+20%
Shannon Point East	5	No trend	-0.056	0.94	No trend	-0.056	0.95	3.86 (3.4-4.9 ha)	-11%
Shannon Point West	5	No trend	-0.100	0.90	No trend	-0.100	0.91	2.59 (1.8-4.0 ha)	-24%

[a] = statistical result was marginally significant (p=0.07); classified as *increasing* (rather than *no trend*) after DNR review

2.4 Discussion

DNR developed a procedure for integrating the 31 MRC floating kelp monitoring sites into the Indicator, effectively assessed 18 sites for trends, and incorporated these findings into the MRC Vital Sign dataset. Four of the 31 sites were excluded due to limited data (i.e., <5 years of data) and no plans to resume sampling. NW Straits staff will review the remaining eight MRC sites for inclusion in the Indicator as resources allow. The data processing steps constitute an ongoing procedure that can be used each year to incorporate the MRC kelp data into the Indicator. The assessment of kelp trends at the MRC sites included two sites as *increasing*, one site as *decreasing*, two sites as *total loss*, and 13 sites as *no trend*. The two sites that showed *total loss* of kelp (Meadowdale and Mukilteo) are located in the more urbanized areas of Central Puget Sound. The full procedure for Indicator site classification is detailed in the Monitoring Program Design and Data Assessment Protocols (Berry et al. 2023) and in the MRC Dataset Description (Appendix 3).

The MRC kelp dataset is an important piece of the Washington Statewide Floating Kelp Indicator because it provides insight into long-term kelp trends across a wide geographic range. The MRC kelp data includes monitoring sites in most of the sub-basins defined in the Monitoring Program Design and Assessment Protocol (Berry et al. 2023). In three sub-basins, Saratoga-Whidbey, Admiralty Inlet, and North Puget Sound, the MRC kelp data is some of the only floating kelp data currently available for inclusion in the Indicator, providing an especially valuable source of assessment information in those sub-basins.

2.4.1 Trend Classification

Quantitative assessment of the data using linear regression provided a trend classification for each site (Table 2). Expert review then integrated the regression results and any additional data and knowledge of the site to either confirm or over-ride the trend assigned by the regression result. In this first round of MRC data incorporated into the Indicator, the p-value cutoff ($p < 0.05$) was relaxed for one site based on expert review (Table 2). The regression analysis classified the recent trend for Ebey's Landing to be *no trend*, but after review of the data and statistics analyses, the kelp bed area classification was changed to *increasing* because the p-value was marginally significant ($p = 0.07$), and the kelp bed area increased substantially between 2018 and 2019 before stabilizing (Appendix 1, Figure 5).

The trend classifications presented in this report are from the first iteration of Indicator trend designations and are impacted by the limited number of years of data. As more data are collected, trend classifications may change. The Edmonds North site is an example of a site where the trend classification could change with additional data (Figure 4). While the kelp bed area is classified as *no trend* for this report, the bed area decreased between 2015 and 2018 and has contracted in spatial extent. Snohomish MRC's continued monitoring of Edmonds North, along with other co-located monitoring at the site, will provide more insight into the long-term kelp trend at the site.

2.4.2 Sources of data variability

There are several sources of data variability present in the MRC kelp data. Bull kelp beds experience a high degree of natural variation from year to year, influenced by environmental factors that may affect kelp growth and survival at different stages of the kelp life cycle. It can be challenging to determine if observed interannual changes in bed area indicate a substantial increase or decrease in kelp or whether it can be attributed to the natural fluctuation of kelp. The MRC kelp monitoring program began in 2015 during a strong marine heatwave that initiated in 2014 (Khangaonkar et al. 2021). Therefore, low values of kelp bed area in early years are expected at sites. It is critical to consider the impact of the Marine Heatwave on kelp bed area when interpreting changes from the baseline.

The MRC kelp data is also subject to random variation due to different observers and field conditions. Meetings with volunteers highlighted differing interpretations of the MRC kayak-based bull kelp survey protocol (hereafter "MRC kelp protocol") which introduces uncertainty into the data. Therefore, the data needs to be analyzed in the context of the notes and observations collected with each survey. Survey notes and observations can provide insights into kelp bed changes or challenges encountered while mapping, affecting how the data is interpreted (see Appendix 2). DNR recommends several ways to reduce the variation between observers and increase survey consistency (Section 4.3); including clarifying the protocol language, providing ample on-the-water training, and setting constraints on field conditions.

Taking both of these sources of variability into account, it is challenging to clearly distinguish substantial change from natural bed dynamics. While some amount of uncertainty is inevitable, results can be honed through further development of methods to reduce variation between sampling efforts. All floating kelp monitoring methods have uncertainty and variability associated with them; however, trends can still be inferred if the sources of uncertainty are minimized and variability is assessed.

2.4.3 Next steps

Before the Indicator Database is updated with the 2022 MRC data, DNR and NW Straits need to update the MRC Dataset Description and data integration steps to clarify which surveys to include when determining the annual maximum bed area. When summarizing kelp bed area in the current workflow, all replicate surveys collected on the same day were averaged to create a single kelp bed area per survey day. However, there is uncertainty in this method because there are some sites with differences in tidal height between replicates. For example, at North Beach in July 2016, there were a total of three surveys but two tested alternative methods, so likely should be excluded from the annual bed area estimate. DNR recommends adding additional attributes to identify which perimeter surveys potentially qualify as annual estimates and which explore other conditions, such as methodological tests, variable tides/currents, or seasonal comparisons. These attributes will be used to identify which perimeters will be integrated into annual maximum bed area estimates.

For this first iteration of the Indicator, DNR worked closely with NW Straits to review and assess the MRC data that was included in the statewide Indicator. In future years, NW Straits staff will conduct reviews and assessments of the MRC data before providing preliminary findings for discussion with the WA Kelp Forest Alliance and integration into annual updates of the Indicator.

This assessment of the MRC data applies the protocol and classification categories of the WA Statewide Floating Kelp Indicator (Berry et al. 2023). However, the MRC kelp monitoring program could expand beyond the current scope of the Indicator. NW Straits could develop other classification categories and assessment considerations based on the MRC dataset for other purposes. Section 4.3.2 details some of the ways NW Straits might enhance and expand the current monitoring program.

The workflow of data collection and processing in this report provides a useful case study for groups who are developing methods to collect and contribute data to the Indicator. During the Indicator creation process, members of the Project Team fielded questions from groups interested in collecting kelp data that could be included in the Indicator. There are many details to consider when developing a long-term monitoring program. This report and the MRC kelp protocol demonstrate important considerations for starting a volunteer-based floating kelp bed area monitoring program.

3 Communication Products

3.1 Introduction

Communication of scientific monitoring studies is vitally important for public engagement and positive conservation outcomes. However, results of many scientific monitoring studies are shared through publications or reports that do not typically reach the diverse and broad audiences intended by community science. The MRC kelp monitoring program works with community scientists to collect data that is relevant to local marine management goals. MRCs showcase the data they collect and inform local county officials and resource managers through annual reports, in person meetings, and their websites, while NWSC also shares it on SoundIQ and an ArcGIS StoryMap created in 2016. A goal of this project was to disseminate the MRC kelp data to a wider audience and highlight the volunteer monitoring program using a variety of products, including additional reports, interactive data maps, and a new ArcGIS StoryMap, a web-based application that can visually tell a story by integrating text with interactive maps and other multimedia content. Integration of the MRC data into the Indicator is a great example of how the volunteer data is being used to inform the statewide assessment of floating kelp, and the associated communication tools provide additional avenues to present the MRC kelp data to a wider audience. A StoryMap provides context to the MRC data and further highlights the program and the volunteers. Early in the development process, DNR and NW Straits decided that development and maintenance of the StoryMap would be led by NW Straits and DNR would lead the development of the Indicator products.

3.2 Methods

During our communication development discussions, we identified two distinct product needs for presenting and visualizing the MRC data for the public. First, we saw a need for a product to highlight the MRC data used in the Indicator. The second need was to present the full MRC kelp dataset on a StoryMap that volunteers could use to further showcase their work and inform local resource managers about kelp status in their area. We were able to address both communication product needs in the project, which are described below.

Creating communication products for the MRC data used in the Indicator was part of a much larger project and included other datasets. The Indicator creation team developed a series of products to report overall findings and location-specific details. Detailed methods of this development, and the community outreach conducted, can be found in the Monitoring Program Design and Data Assessment Protocols (Berry et al. 2023).

To develop the MRC StoryMap, DNR and NW Straits held a series of meetings to (1) review the existing MRC StoryMap and SoundIQ web map, (2) discuss aspirations for the new StoryMap, (3) examine other StoryMaps for features to include, (4) identify content to include, and (5) identify communication goals and target audiences. Through these meetings, DNR and NW Straits collaboratively developed a StoryMap outline (Appendix 5) and a StoryMap using ArcGIS Online.

3.3 Results

3.3.1 Floating Kelp Vital Sign Indicator Products

The Indicator Project Team worked collaboratively to create communication products that synthesize Washington State floating kelp data, including the MRC data. The products include:

- Interactive map – visualizes all datasets in the Indicator and provides customized site-level summaries. Map layers include:
    - Sub-basin status uses quantitative data as well as other ways of knowing to place each sub-basin in one of five categories (stable, concern of declines, substantial documented declines, insufficient data, no floating kelp)
    - Long-term trends at locations uses all quantitative data over the entire data record and one of six trend categories is applied to each location based on statistical analysis and expert review (increasing, no trend, decreasing, total loss, limited data, no floating kelp)
    - Floating kelp – bed extent in most recent year visualizes the kelp bed extent in the most recent year data was collected.
    - Floating kelp – maximum extent in all monitoring years visualizes the maximum extent that kelp was found at a location throughout all the monitoring years.
    - One-page data summary for each location – For the MRC sites, each summary includes a graph, site map, short paragraph of the findings, and a photo. Links to the local MRC, NW Straits, and SoundIQ websites are included on the summary page (Appendix 6) (Berry et al. 2023).
- Statewide Summary Report – statewide assessment of floating kelp through 2021.
- Monitoring Program Design and Protocols – technical report that describes the program design and data assessment protocols for statewide monitoring of floating kelp in Washington.
- Puget Sound Partnership PS Info webpage – the Floating Kelp Bed Area Indicator as reported on the Puget Sound Vital Signs PS Info website under the Beaches and Marine Vegetation Vital Sign.

3.3.2 MRC Kelp StoryMap

DNR and NW Straits determined that the main messages to convey through the StoryMap should be (1) how the MRC community scientists contribute to our understanding of kelp in Puget Sound, (2) the value of engaging communities and volunteers to monitor kelp, and (3) to highlight key findings from the MRC surveys. The target audiences for the StoryMap were identified as MRC volunteers, county officials, local communities, and local planners.

Using the StoryMap outline developed in 2022 (Appendix 6) as a guide, DNR and NW Straits collaboratively built the MRC Kelp Monitoring StoryMap on ArcGIS Online. The StoryMap included the following sections: Overview, Key Outcomes, Interactive Data Map, Clallam MRC, Island MRC, Jefferson MRC, San Juan MRC, Skagit MRC, Snohomish MRC, and Whatcom MRC and utilized photos and video captured by volunteers and maps and graphs to facilitate data exploration.

3.4 Discussion

The communication products for the WA Statewide Floating Kelp Indicator were released in May 2023. DNR developed additional communication tools showcasing datasets used in the Indicator, including the MRC data (e.g., Appendix 6). DNR and NW Straits developed a visually engaging, informative, and interactive MRC kelp StoryMap to showcase the MRC kelp monitoring program and its data.

Effective communication products are important tools to increase program awareness and share findings to target audiences including the volunteers, local residents, elected officials, and local planners. For the MRC kelp monitoring program, NW Straits wanted to convey the value of kelp forests and community science and to highlight key findings through communication products. In addition, county MRCs wanted to present the important data to inform local resource managers, elected officials, and residents. Interactive maps, reports, and a StoryMap showcase the volunteer program, the data and results, and highlight how these data are being used to achieve habitat conservation and protection goals. Powerful communication tools can also aid in recruiting new volunteers from the community and securing funding for future monitoring and research.

Dissemination of these products provide an opportunity to gather feedback on them from the community. For example, DNR presented an update on the Indicator and introduction to the interactive map to MRC volunteers at the MRC Kelp Kayak Data Review Workshop hosted by NW Straits on January 19, 2023. Volunteers had positive responses and several counties expressed enthusiasm for improving/increasing kelp data collection in their regions.

4 Recommendations

4.1 Introduction

Since 2015, volunteers have mapped their local kelp beds through the MRC kelp monitoring program. This data has been reviewed, compiled, and basic analyses has been shared with county officials and managers, but can benefit from more extensive analyses. One goal of this project was for DNR to recommend improvements to methods, spatial coverage, and monitoring parameters. This section describes potential improvements that were identified by DNR during the process of data analysis and interpretation.

4.2 Methods

DNR met with NW Straits staff biweekly, between September 2021 and June 2023 (30+ meetings), to discuss data processing and interpretation, communication product development, and data collection enhancements. These regular meetings helped DNR and NW Straits identify areas of potential improvement and develop solutions. In addition, through data review and interviews with volunteers, DNR identified areas of uncertainty, and prioritized them based on the degree of impact they exerted on the utility of MRC kelp data.

The MRC kelp monitoring program review included DNR participation in MRC kayak surveys at Possession Point (Island County), North Beach (Jefferson County), and Cherry Point (Whatcom County) in 2022. DNR worked in the field with volunteers to test a draft protocol enhancement, delineating the extent of the survey on the water. A 2020 update of the MRC kelp protocol introduced pre-defined lengths of shoreline (i.e., “shoreline segments”) for volunteers to survey, to standardize the area volunteers monitored during each survey and allow for temporal comparisons of each site. The 2022 draft protocol enhancement had surveyors record survey start and end points used to document the actual along-shore distance covered during each survey. Recording this actual distance helps confirm that surveys cover the full pre-defined shoreline segment. Based on the ease and success of piloting this change, all surveys in 2023 will record the new survey endpoints. Additional methodological changes were proposed and adapted into the 2023 MRC kelp protocol (e.g., increased number of minimum and maximum depth and temperature measurements, decreased number of bed photos taken, clarified threshold language, etc.) but were not tested in the 2022 field season.

DNR also brainstormed about potential program expansions that are beyond the scope of current work conducted by NW Straits and the MRCs (Section 4.3.2). These enhancements represent new efforts to collect expanded datasets and employ additional monitoring methods to fill knowledge gaps and provide valuable data to the kelp research community.

4.3 Results

The MRC kelp monitoring program has the potential to provide valuable insights about local kelp dynamics. However, DNR Nearshore Habitat Program scientists estimate that the MRC kelp monitoring program only has sufficient staff resources for volunteer coordination, basic data processing, and data sharing on SoundIQ. DNR Nearshore Habitat Program scientists recommend that a full-time staff member is needed for data quality assessment, interpretation and distribution. Program findings have two immediate outreach platforms: 1) the statewide Indicator; and 2) independent communication tools developed by NW Straits and the MRCs, including the MRC Kelp Monitoring StoryMap (Section 3.3.2). Looking forward, protocol refinement would likely require additional staff resources and expertise as well.

The following sections provide specific recommendations for improvements, grouped according to enhancements to the existing program and potential program expansion.

4.3.1 Enhancements to the existing monitoring program

Field notes and conversations with volunteers about site dynamics, survey insights, and impressions led us to identify the following key recommendations and considerations for future data collection (highest priorities are in **bold**):

1. **Define a shoreline segment and record survey endpoints for each site,**
2. **Set constraints on survey field conditions,**
3. **Improve consistency in applying protocol threshold distance,**
4. Expand monitoring to additional sites as volunteer interest at capacity allows,
5. Co-locate monitoring sites with other entities, and
6. Consider protocol improvements while maintaining backwards compatibility.

4.3.1.1 Define a shoreline segment and record survey endpoints

During the initial review of data for inclusion in the Indicator, the biggest challenge in comparing data between years was uncertainty in the alongshore distance that was surveyed for kelp each year. To accurately compare kelp bed area over time, it is important to know that the surveys covered the same footprint each time and to distinguish between areas where kelp is absent and areas with 'no data'. This is particularly important at sites where kelp bed locations shift and/or merge with adjacent kelp beds. To obtain this additional information for past surveys, DNR interviewed volunteers with survey experience at each site and through discussion and review of past survey data, defined and created an Indicator survey extent that represents the area consistently mapped over time (see Section 2.2 and Appendix 3 for more detail on this process). However, the Indicator survey extents were only created for the 18 sites included In the Indicator and not for the entire MRC dataset.

In 2020, NW Straits addressed the challenge of maintaining a consistent survey footprint by adding the use of "shoreline segments" into the protocol at some but not all sites (Figure 5). The shoreline segments created spatial boundaries along a length of shoreline at monitoring sites that were used as guidance by volunteers so they could return to the same area each year to survey. The shoreline segments were often based on landmarks visible from the water and visualized as line segments perpendicular to shore to designate the segment. The 2020 MRC kelp protocol instructed that when surveying, all kelp (beds and individual bulbs) be mapped within the shoreline segment boundaries. While this was a good first step to standardize the survey footprint, there are improvements that could be made and additional data that could be collected to enhance the usefulness of the shoreline boundary segments that would result in higher quality perimeter data.

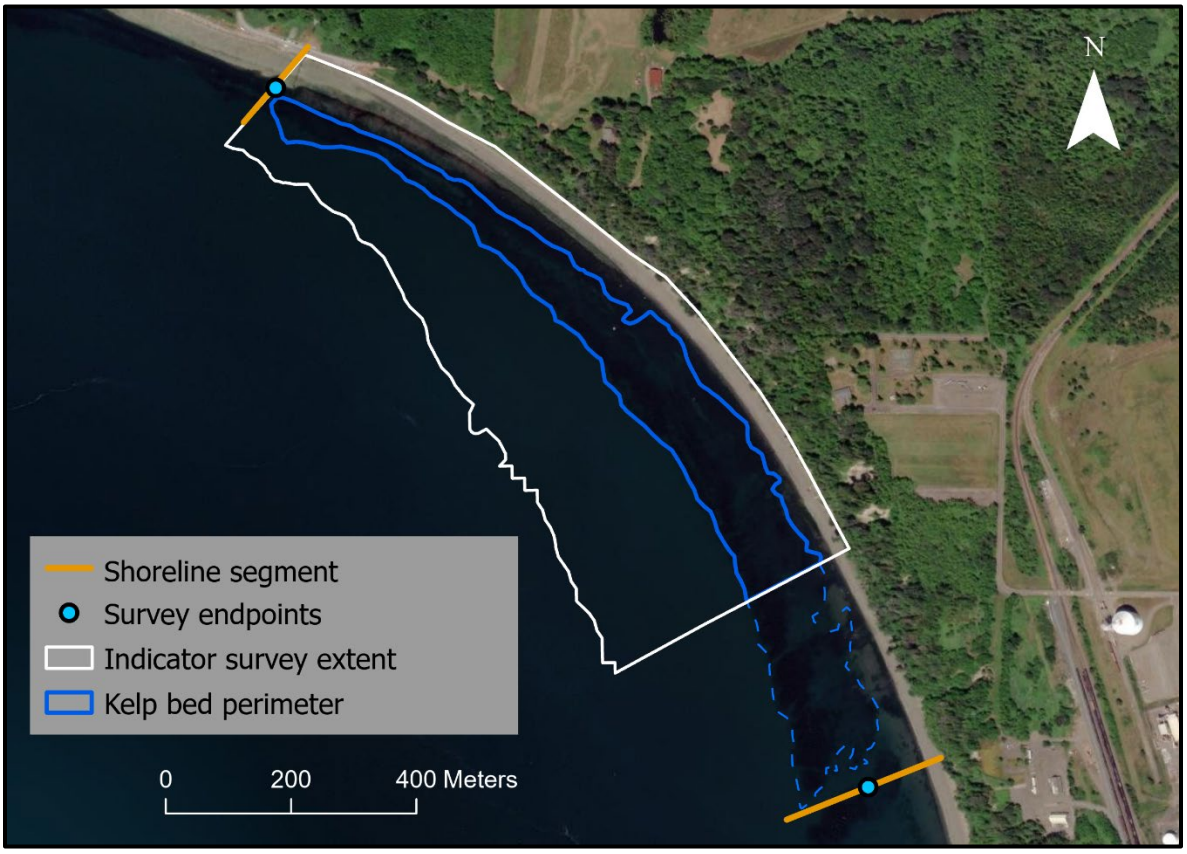

Figure 5. Cherry Point MRC kelp monitoring site in Whatcom County, WA. The pre-defined shoreline segment (orange lines) identifies the length of shoreline that should be surveyed and survey endpoints (blue points) should be taken during a survey to confirm the entire shoreline segment was surveyed. The Indicator survey extent (white polygon) represents the area that has been consistently surveyed over time (for this site 2017-2021). The kelp bed perimeter collected in 2020 (blue polygon) covered the entire shoreline segment but the section of the bed with the dashed line perimeter was excluded from the Indicator since that section was not consistently surveyed over time. Only the bed area with the solid blue line was included in the indicator.

Moving forward, it would be highly beneficial to the MRC kelp monitoring program to establish a shoreline segment for each site prior to the survey effort itself. The most important additions to the shoreline segment concept include: (1) defining shoreline segments for every site (with a few exceptions for sites offshore, e.g., Coffin Rocks) and (2) creating methods to record the alongshore distance actually covered by each survey. There was a consensus between NW Straits and DNR that the best thing to do to address this challenge was to update the 2020 shoreline segment protocol (see below).

The following steps were implemented to update the shoreline segment protocol (reflected in the 2023 MRC kelp protocol):

1. Emphasize the definition of "shoreline segment" to make its meaning more explicit. It should be the minimum alongshore distance that volunteers paddle during each survey.
2. Inform volunteers that they can survey beyond the defined boundaries, but that every survey needs to at least cover the along-shore distance defined by the shoreline segments.
3. Confirm existing shoreline segment boundaries with volunteers from each site and create new shoreline segment boundaries for sites without existing boundaries with guidance from site volunteers.
    a. Convey the difference between shoreline segments for future surveys and Indicator survey extents to volunteers and what data is needed to include a site in the MRC Indicator dataset. To have a site included in the MRC Indicator dataset, the entire Indicator survey extent needs to be mapped, but volunteers can survey beyond the Indicator survey extent if desired (see Figure 5).
4. Update the shoreline segment protocol to have volunteers take GPS waypoints to explicitly mark the distance surveyed, called "survey endpoints" (Figure 5). The first waypoint should be taken once all volunteers are on the water and actively looking for kelp (whether or not kelp is present). This would represent one survey endpoint and likely to correspond to a boundary of the shoreline segment. A second waypoint should be taken at the furthest point the volunteers paddle before they turn around. This would represent the second survey endpoint and likely be at the far boundary of the shoreline segment. These two waypoints will be recorded on the datasheet and uploaded into KoboToolbox to be compared to the pre-defined shoreline segments. The survey endpoints should, at a minimum, span the same segment of shoreline defined for the site (but may go beyond the shoreline segment) and confirm that the survey is comparable to other surveys.
5. Update the field datasheet to include a section to record the survey endpoints (updated datasheet in the 2023 MRC kelp protocol).

4.3.1.2 Set constraints on survey field conditions

After interviewing volunteers in each county and reviewing all the survey observations and notes, several common challenges encountered while mapping were identified. The mapping challenges fell into two general themes: (1) the effect of tides and currents on visibility of kelp plants at the surface and (2) the effect of weather and water conditions on visibility of kelp plants at the surface. Appendix 2 includes a selection of survey notes that address these mapping challenge themes. In this section, each of these themes is discussed using examples from MRC kelp dataset as well as suggestions on how to address them.

Tides and Currents

When mapping kelp beds by kayak, tidal height and currents can affect the results and should be taken into account when picking an optimal survey window. The 2020 MRC kelp protocol recommended mapping the kelp beds at a low tide of less than 0.0 ft MLLW (Mean Lower Low Water) and reminded volunteers to keep current in mind when selecting survey days. However, choosing any low tide below 0.0 ft MLLW leaves a wide range of tidal heights to survey at. In Puget Sound, that range is from 0 ft MLLW to -4 ft MLLW. Mapping kelp without considering the height of a low tide could impact the usefulness of the data. Surveys conducted at a -1 ft and -3 ft tide MLLW could result in very different mapped perimeters that may not be able to be accurately compared.

Tidal height and current go hand-in-hand, and their interaction should also be considered when choosing when to survey kelp beds. During an incoming or outgoing tide, the current can pull the deep edge of a kelp bed underwater, making the plants hard to see from a kayak. Around the low tide, the current goes slack and kelp plants are more visible on the surface. However, each site has its own dynamics and slack current can be offset from low tide and vary with proximity to shore. Current stations in the middle of a channel may not represent the current regime experienced close to shore. Additionally, extreme low tides (around -3 ft MLLW) can have stronger currents because more water is flooding in and ebbing out which affects how much kelp is visible at the surface. These considerations mean that there is not a one-size-fits-all approach for determining the best survey windows for each site.

An example of how current can impact the accuracy of kelp data can be seen in Figure 6. At the North Beach kelp bed, DNR scientists recorded the minimum and maximum depth of kelp along 13 transects and overlaid them on fixed-wing aerial imagery of the site (Figure 6). Overall, the deep edge points generally match up with the deepest plants seen in the imagery. However, in the middle of the bed there are two depth measurements where the imagery shows kelp deeper than the depth point taken (red points on map). These two transects were surveyed at the end of the two-hour survey window (1 hour on either side of low tide) and by the time they were reached, the current had pulled the deepest plants under the surface.

Based on this example, and notes on tides and currents in Appendix 2, DNR and NW Straits added more clarification and explicit guidelines in the 2023 MRC kelp protocol to map kelp at a similar tide at slack current for each survey to add more consistency and result in perimeters that are comparable.

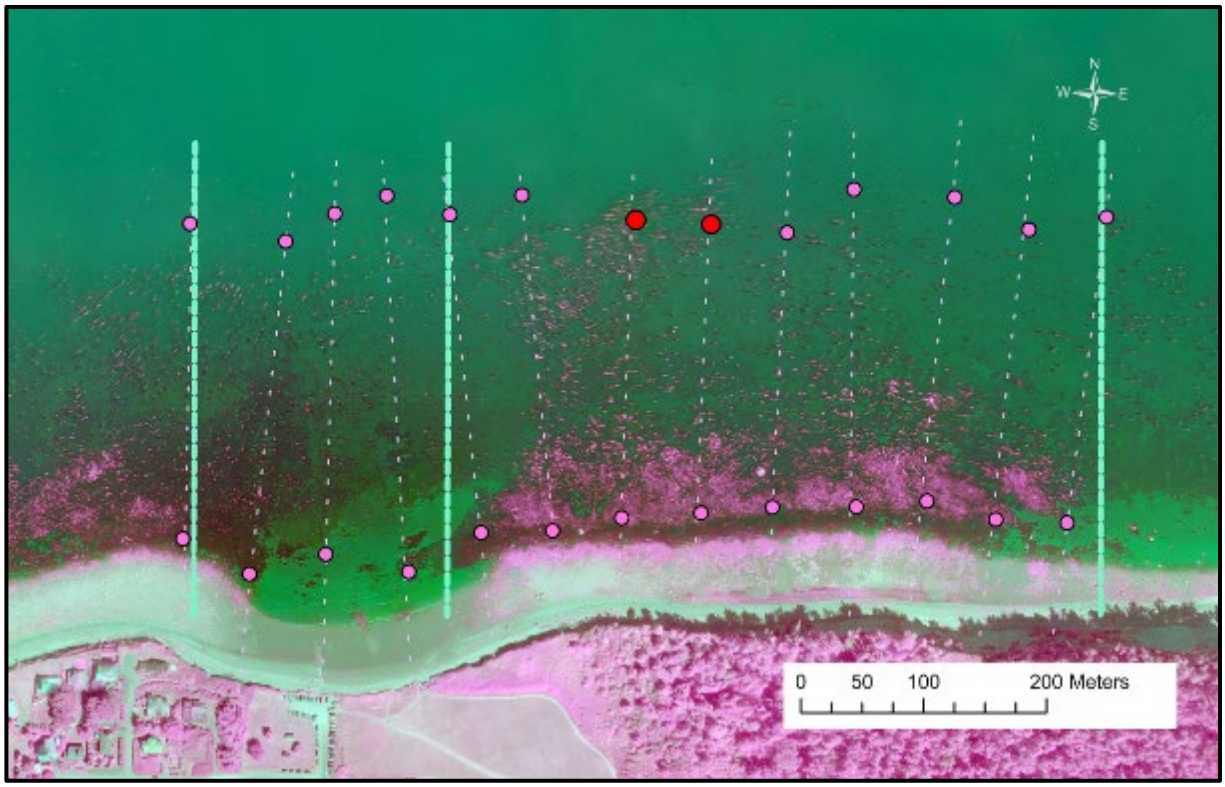

Figure 6. Fixed-wing imagery of the North Beach MRC kelp site, Jefferson County, WA from August 24, 2021, with minimum and maximum depths of kelp (pink dots) along 13 transects (dashed lines) collected by DNR on August 9 and August 20, 2021. Red dots indicate where depth measurements collected during kayak-based surveys differ from fixed-wing aerial imagery.

Because low tide and slack current can influence the amount of kelp visible on the surface, DNR recommends that NW Straits works with each MRC to identify and implement ideal survey windows for each site based on low tide and slack current time and behavior. To do this, each site would use current and historical tide and current data, as well as volunteer knowledge and observations, to define the window of time around low tide/slack current when the kelp is most visible. As these windows are developed, volunteers should take note during surveys of changes in the tide or current behavior and their relation to the time of low tide and/or slack current. These site-specific survey windows will provide guidance to volunteers as they schedule kelp surveys and help increase data consistency.

Weather and Water Conditions

Weather and water conditions can influence the ability to capture the maximum extent of kelp on any given day. Wind, wave action, and low visibility can affect what kelp volunteers can see and safely map. The 2020 MRC kelp protocol directed volunteers to ensure that safe weather and maritime conditions are projected and to keep safety in mind but does not outline an acceptable range of survey conditions. Many of the survey notes mentioned 10-15 kt winds and swell that impacted what kelp could be seen and mapped. For example, notes for the 2020 Clallam Bay survey mention that volunteers had to rush the second half of the survey due to

weather conditions and intentionally mapped the bed smaller than it was to avoid waves and rocks. Due to this purposely smaller bed perimeter, it is difficult to know how accurate a yearly comparison would be.

While some sudden weather changes are unavoidable, NW Straits and DNR added an explicit step in the 2023 MRC kelp protocol to check the wind speed/direction and the marine forecast before every survey. General parameters for ideal wind speed and wind wave heights were also added to the protocol to aid in survey planning. DNR's kelp monitoring program in South and Central Puget Sound aims to survey DNR monitoring sites when wind is much less than 10 kts and wind waves are 1 ft or less (depending on the wind direction and site). This might not be practical for all the sites, but it could be a good starting point, as each MRC develops realistic/feasible parameters for their sites. The wind direction can also influence conditions and survey success. Depending on the wind direction, higher wind speeds can either create choppy survey conditions at a site or create minimal impact on water conditions. Identification of optimal wind direction and wind velocities for each site, along with thresholds to cancel sampling, would improve kelp bed area data and volunteer safety.

4.3.1.3 Improve consistency in applying survey distance threshold

When reviewing the survey data and field notes and interviewing volunteers, it became apparent that one of the challenges for data usability was consistently applying the survey distance threshold defined in the protocol. Accurately interpreting the protocol's kelp bed definition and consistently applying it during surveys increases data accuracy and comparability. The MRC kelp protocol defines kelp beds as a cluster of plants (i.e., >10 bulbs) greater than 5 m across, and further states that individual plants greater than 8 m apart are to be considered part of a separate bed. Assessing distance over water from a kayak can be challenging and individual volunteers can perceive distances differently (e.g., Figure 7, described below). Survey notes referencing the survey distance threshold and what kelp to include in perimeters can be found in Appendix 2. There are also visual examples in the perimeter data that show how different interpretations of the survey distance threshold by different volunteers can lead to differences in bed area.

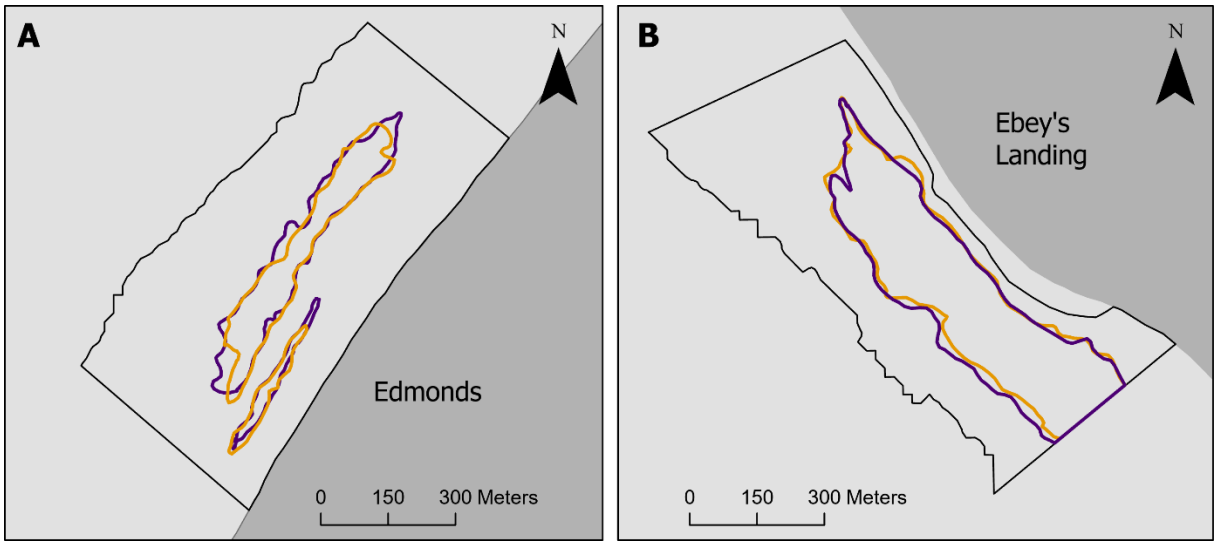

Figure 7. Floating kelp bed area at Edmonds North, Snohomish County, on July 20, 2016 (A) and Ebey's Landing, Island County, on August 30, 2020 (B). Purple and yellow lines represent survey replicates at each site. Black polygons represent the Indicator survey extent.

In some cases, replicate surveys conducted on same day show variation in perimeter and bed area. For example, on July 20, 2016, two replicate perimeters were collected at the Edmonds North kelp beds and while they are visibly distinct (Figure 7A), the bed area differed by just 0.6 ha (5.0 to 5.6 ha). Similarly, the two replicate perimeters were collected at Ebey's Landing on August 30, 2020 differed in bed area by 0.4 ha (14.0 and 14.4 ha, Figure 7B). Since these surveys are conducted on the same day, eliminating many other variables, some of the difference in perimeters could be attributed to differences in application of the survey distance threshold. However, the magnitude of inconsistent application of the survey distance threshold can vary by site. Perimeters collected at North Beach in 2021 highlight the varying interpretation of the survey distance threshold by volunteers. This difference is especially noticeable when the perimeters are overlayed on aerial imagery collected on August 24, 2021 (Figure 8). This allows for a rough comparison between the kelp seen from an on-the-water kayak survey and kelp visible from the air during an aerial survey. While the surveys were not collected on the same day, one bed perimeter (in yellow) meets the defined survey distance threshold more closely than the other perimeter (in blue) (Figure 8). Areas of sparser kelp (that could be more than 8 m apart) seen in the imagery were included in the blue kayak perimeter (and not the yellow perimeter), reinforcing that application of the survey distance threshold can be challenging and variable between volunteers and sites.

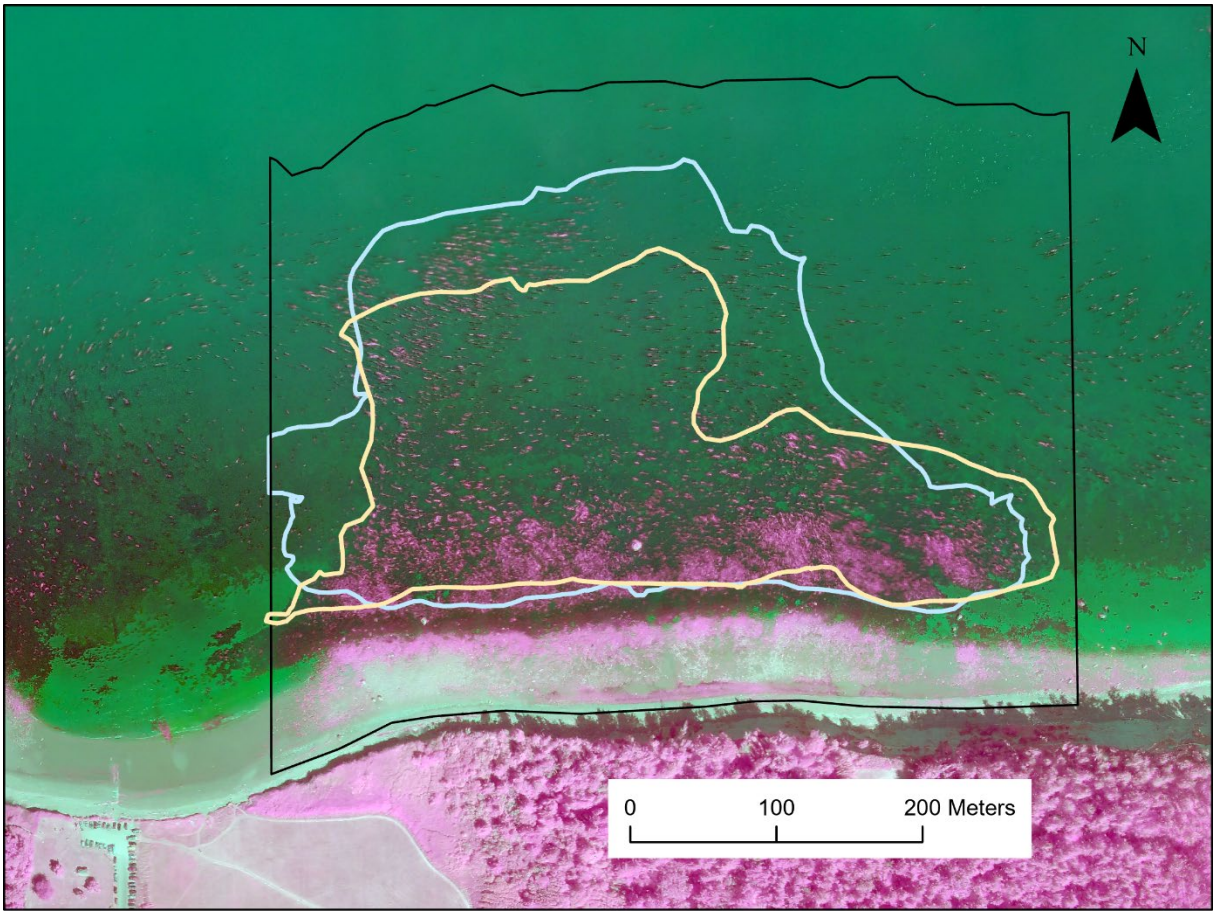

Figure 8. Floating kelp bed area at North Beach, Jefferson County, WA. Kayak-surveyed perimeters from June 22, 2021 (yellow) and August 20, 2021 (blue) and aerial imagery collected on August 24, 2021. Black polygon represents site extent.

It is important to continue to emphasize all volunteer survey participants review the survey distance threshold at the start of each field season, and prior to sampling any kelp bed, so each survey is as accurate as possible and comparable to past and subsequent surveys. NW Straits and the MRCs could how to formalize on-the-water or on-land training/refreshers each year for estimating distances and working with fellow volunteers to calibrate to each other. For example, DNR scientists visualize the distance on the water with a measuring tape each spring to refresh their estimation and calibrate to each other before surveys begin. DNR also considers kayak or paddle length when estimating distances over water. Emphasizing the role of this extra practice at the start of each season will help to increase the accuracy of surveyed perimeters.

4.3.1.4 Expand monitoring to additional sites

The 22 MRC floating kelp monitoring sites surveyed in 2021 are distributed across northern Puget Sound and the Strait of Juan de Fuca, but there are options for expanding the current monitoring, given sufficient resources. Adding new sites is dependent on what each MRC is

capable of managing and staffing with volunteer kayakers, but if there is interest and capacity, there are several ways to approach site selection. When choosing new monitoring sites, MRCs can consider a few options, including adding sites with varying bed dynamics and adding sites in areas of special interest or limited data.

In talks with volunteers, there were discussions about neighboring kelp beds exhibiting different dynamics which could be informative to track. For example, the surveyed Biz Point kelp bed changes little year to year, but neighboring kelp beds to the north and south have been observed to experience large year-to-year fluctuations (J. Freeto, P. Latendresse, *pers. comm*.). Documenting neighboring beds would enrich the understanding of bed dynamics in an area and provide the ability compare beds to one another. Adding sites in areas of special interest or areas of limited data would not only benefit the MRC floating kelp dataset but it would also provide more sites that could inform the Indicator. MRC areas with limited kelp bed data include North Puget Sound, the Saratoga-Whidbey basin, Admiralty Inlet, and Central Puget Sound. DNR and NW Straits will continue to work with the Indicator project team to identify candidate areas for additional sites.

MRCs could choose to monitor sites in alternating years if adding new sites is beyond the means of existing volunteers. Either approach for adding sites (annual or variable sampling) will integrate easily with the current MRC kelp database; however, any site included in the Indicator will need to be surveyed annually to provide consistent long-term data.

4.3.1.5 Co-locate monitoring sites

It would be synergistic to co-locate MRC sites with other monitoring efforts, as it would expand our understanding of certain sites based on an array of different data types. Some co-location of monitoring sites is already in place. For example, Puget Sound Restoration Fund (PSRF) created a kelp index monitoring site co-located with the two MRC Edmonds sites. The PSRF dive surveys and environmental sensors at the Edmonds index site will complement the MRC kayak surveys by providing a multifaceted view of kelp at the site. Additionally, DNR has co-located collection of aerial imagery and minimum and maximum depth of kelp at the MRC North Beach and Edmonds North sites, which will add to the understanding of kelp dynamics and trends at these sites.

Through KelpForestsWA and other kelp efforts in Puget Sound, co-location of sites would benefit not only participating organizations but would expand the knowledge of kelp dynamics in the region and develop a more collaborative kelp community.

4.3.1.6 Consider protocol improvements while maintaining backwards compatibility

The MRC kelp monitoring program uses the MRC kelp protocol written in 2014 and updated in 2016, 2020, and 2023. Making methodological changes to the protocol after years of use can have both advantages and disadvantages. Refining methods, adding metrics, and increasing data usability benefit the dataset but consistency in data structure should be prioritized. We identified several potential protocol improvements and additions for NW Straits to consider and some were implemented in the 2023 MRC kelp protocol. However, as

changes are made to the existing protocol, it is important to maintain backwards compatibility with methodological changes to ensure older data can be accurately compared to new data.

The MRC kelp protocol was originally developed to survey kelp beds that were suitable rockfish habitat (E. Bishop, *pers. comm.*). As was discussed in Section 4.3.3, the survey distance threshold for determining if kelp should be considered part of the bed or a separate bed is 8 m between floating kelp plants (plant is defined as an attached stipe with a floating kelp bulb and blades). This 8 m spacing between kelp plants could be a good indicator of ideal rockfish habitat, but some sparse kelp beds may have kelp that is more diffuse and might not meet the threshold. In such cases, much of the sparse bed would not be surveyed and the perimeter might represent a fraction of the bed. In kayak surveys conducted by DNR in South and Central Puget Sound, where many kelp beds are sparse, a threshold distance of 25 m is used to determine which kelp is included in the bed. With this larger survey distance threshold, a more complete bed area is captured for a sparse bed. NW Straits will need to consider if it would be worthwhile to update the threshold distance and, if so, how best to do it to maintain backwards compatibility.

In addition to considering changes to the survey distance threshold, there are several other changes or improvements that have been or could be added to the MRC kelp protocol. First, we clarified the language on when and where to take GPS points for individual bulbs/clusters. While the 2020 protocol included instructions for taking GPS points at individual bulbs/clusters, interviews with volunteers revealed there was some confusion about when and where to apply the step. The 2023 updated protocol emphasizes that taking GPS points at individual kelp bulbs or clusters is only necessary if no kelp bed is present at the site.

Second, additional minimum and maximum depth measurements along the bed perimeter were added to the 2023 MRC kelp protocol. DNR collects this metric at all DNR kelp monitoring sites to track the shallow and deep edge of the kelp bed. Minimum and maximum bed depths can give insight into whether the depth distribution of kelp is changing. As ocean temperatures warm, there could be a shift of the shallow edge of the bed into deeper, cooler water. Volunteers previously took one depth measurement on the shallow edge of the bed and one on the deep edge. The updated 2023 MRC kelp protocol increased the number of depth measurements to two on the shallow and deep edges of the bed. While adding minimum and maximum depth measurements to the protocol increases the stopping time during the perimeter survey, more depth measurements would enhance understanding of bed depth distribution. Many potential approaches to increasing the number of depth measurements exist. For example, DNR collects approximately 13 minimum and maximum measurements per site. However, DNR's methodology may not be optimal for the volunteers. An absolute minimum from a descriptive statistics perspective would be three measurements, which would allow for calculation of a mean and standard error. DNR could explore alternative methodologies with NW Straits that considers volunteer capacity.

Finally, the data would benefit from increasing the number of replicate perimeter surveys to at least three. Collecting three perimeters on the same survey day would allow more robust statistical analyses to minimize the impact of observer difference and changes in

environmental variables between surveys. For small sites, it would be minimal extra effort to record the bed perimeter several times during the low tide window without needing additional volunteers or GPS units. For larger sites, collecting three perimeters would involve using several GPS units and having volunteers potentially split into smaller groups to capture multiple perimeters during one low tide window. This proposed improvement to the protocol would only be possible if there are sufficient volunteers and conditions are safe. This was not added to the 2023 MRC kelp protocol but could be considered in the future.

4.3.2 Potential program expansion

The majority of this project focused on integration of the MRC kelp data into the Indicator. However, the MRC kelp monitoring program could be expanded beyond the current scope of the Indicator. There are many potential directions that NW Straits and the MRCs can consider when evaluating their organizational priorities and capacity, including:

- Analyze and interpret other existing data streams,
- Monitor environmental conditions,
- Monitor usage of kelp beds by fish, birds, invertebrates, and mammals,
- Expand monitoring methods,
- Expand species monitored, and
- Extend the time span of long-term trends through integrating historical data.

The MRC kelp monitoring program currently collects more data than is incorporated in the Indicator, including bed depth, surface water temperature, and the species observed during the survey. These existing data streams could be analyzed and interpreted to inform improvements and enhancements to the current monitoring program. Development of many of the proposed program expansions would benefit from analysis of these existing MRC datasets. For example, the MRCs could monitor environmental conditions, including water temperature, turbidity, and adjacent land use. While the MRCs already collect surface water temperatures at several points along the perimeter, continuous monitoring of water temperature would give more insight into the thermal conditions that kelp experience. Collecting these physical parameters could increase understanding of the factors driving floating kelp trends. Some surveyors record anecdotal observations of species seen or deploy GoPro cameras but the MRCs could create a formal protocol for monitoring the usage of kelp beds by fish, birds, invertebrates, and mammals. Information about local animals can also engage resources managers, policy makers, and other members of the community.

In addition, NW Straits and the MRCs could expand their kelp monitoring program in several other ways. First, the MRCs could use other monitoring methods including Uncrewed Aerial Systems (UAS) and underwater imagery. Expanding monitoring methods could provide complementary data to the program's current datasets and provide insight into kelp dynamics. The MRCs could also expand the number of species the program monitors. The program currently only monitors floating kelp (bull kelp and giant kelp) but there are 22 species of kelp in Washington State and more than 600 species of algae. Kelp and algae support the ecosystem through primary production and habitat provision. Monitoring additional species of kelp and algae could increase understanding of species interactions and competition.

Lastly, NW Straits and the MRCs could work to extend the time span of long-term kelp trends by integrating historical data. Many of the counties with MRCs have substantial information gaps and only a short time span of kelp data. Through identifying diverse information sources (e.g., historical nautical charts or observations), MRCs could fill gaps and extend temporal baselines to better understand long-term trends in kelp.

4.4 Discussion

To date, MRC kelp monitoring staff support efforts have focused on volunteer coordination, basic data processing, and data sharing. With additional staff resources to complete data quality assessment, interpretation, and distribution, the program could increase its contribution of insight into local kelp trends. DNR Nearshore Habitat Program scientists recommend that a full-time position is needed to support this work. Additionally, the program could move beyond implementing enhancements to the existing monitoring program and expand the program. To assist future scoping, this report groups recommendations into these two categories: enhancements and expansions.

The top priority recommendation for current program enhancement is to record survey endpoints for every survey at each site, greatly enhancing the usability of the data. Based on the ease and success of recording survey endpoints on the water in 2022, all surveys in 2023 could reasonably use the survey endpoint protocol. Setting constraints on field conditions for surveys and consistently applying the protocol threshold also fall high on the priority list of recommendations to improve data usability and more explicit language was added to the 2023 protocol, along with recommendations for increased training. Identifying and implementing site-specific survey windows to target the most ideal tide and current conditions would also contribute to survey consistency. The other three recommendations (adding new sites, co-locating monitoring sites, protocol improvements) could be implemented more gradually as the MRCs and NW Straits see fit.

This project included the analysis and interpretation of kelp bed area data collected by the MRCs, which is only one piece of the larger dataset that is collected during the MRC kayak kelp surveys. While the additional data collected varies by MRC, most surveys have collected surface water temperature, kelp bed depths, and a list of species observed. Because of time constraints, we were unable to fully assess all information gaps in the data. However, if technical expertise is available to work on the MRC kelp data in the future, DNR recommends that future analysis efforts include bed depth information and the species list. Comparing seasonal and yearly shallow and deep depth measurements could provide valuable information on whether the depth distribution of kelp at a site is shifting. While water surface temperature is an important indicator for kelp growth, measurements at a single point in time do not give much insight into the range of conditions the kelp experience throughout the day/season/year. To capture the range of surface water temperatures that kelp experience at a site, MRCs could deploy a temperature sensor to an existing buoy that would collect continuous temperature data over the year/season. Alternatively, MRCs could work to co-

locate kayak monitoring sites with other groups that are collecting temperature and other environmental parameters (e.g., PSRF, DNR).

The potential program expansion ideas presented in the results are meant to guide future program development discussions within NW Straits and the MRCs. Many MRCs have asked DNR about what additional data collection would be beneficial. The recommendations presented in this report are intended to support the short- and long-term goals of NW Straits and the MRCs, and each MRC would need to consider program priorities and capacity before implementing these recommendations.

It is important to continue to empower volunteers to think about their surveys as part of a multiyear monitoring program that benefits from consistent, comparable data. Volunteers should be encouraged to be involved in the interpretation of their data and take the lead in thinking about their observations and the implications for their local kelp bed/s. As protocols and kelp mapping methods in Puget Sound evolve over time, DNR and NW Straits intend to use adaptive planning to coordinate kelp monitoring efforts. Both entities have a desire to keep the MRCs involved in Puget Sound kelp monitoring and will work to include them in any future methodological changes.

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Appendix 1: Graphs and maps for MRC Indicator Sites

This appendix contains graphs and maps for each MRC kelp indicator site with the classification notes. Long-term and recent trend classifications are the same for all sites, only the long-term trend regression results are reported in each figure caption. Additional regression results can be found in Table 2 in Section 2.3.2.

Biz Point

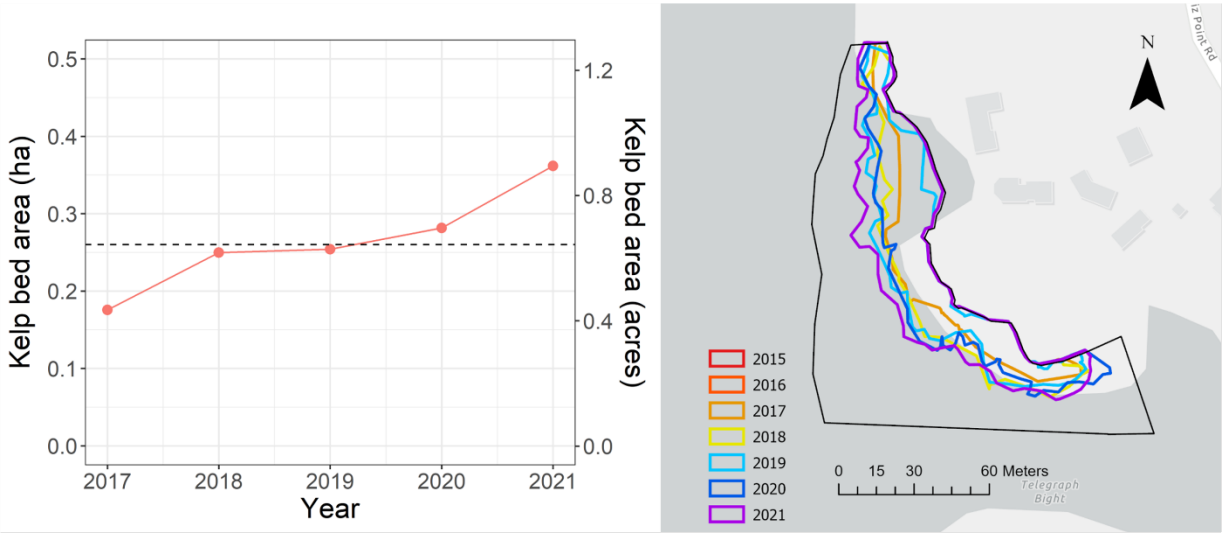


Figure 1. Biz Point graph of maximum bed area per year with long-term mean (dashed line) and map of corresponding survey perimeters. Black polygon in map represents site extent. Bed area increased from 0.17 ha in 2017 to 0.36 ha in 2021. Most of the change in area was concentrated on the deep edge of the bed. Change to the shallow edge was not assessed because a standardized shoreline along the rocks was used for safety. Volunteers noted that the kelp seemed denser in recent years and has started to grow further south into Telegraph Bight, which could account for the slight increase. Classified as *no trend* because the long-term trend regression found the increase in bed area was not significant (p = 0.96).

Cherry Point

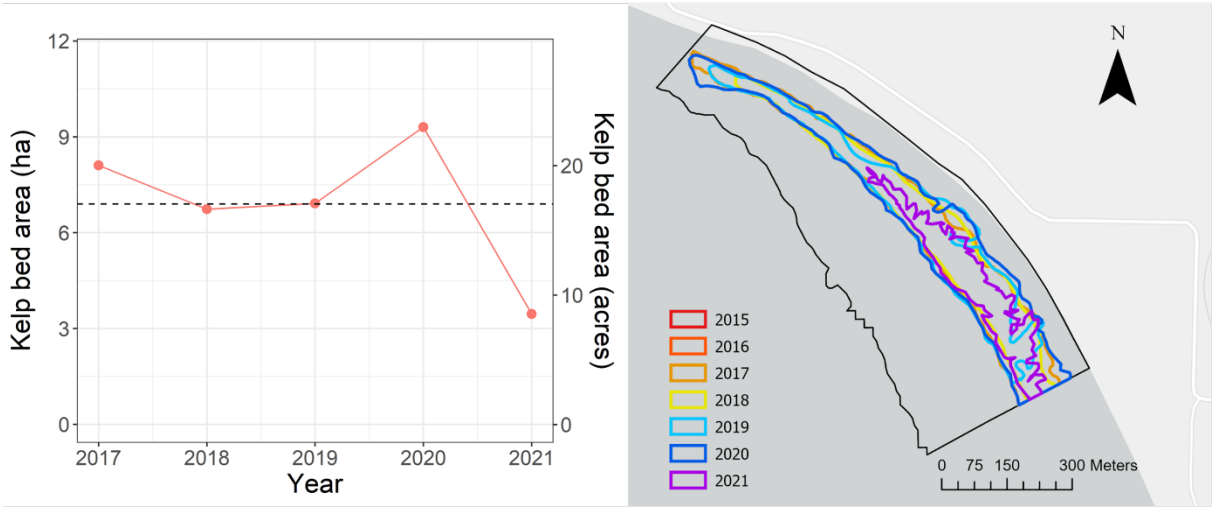


Figure 2. Cherry Point graph of maximum bed area per year with long term mean (dashed line) and map of corresponding survey perimeters. Black polygon in map represents site extent. Bed area between 2017 and 2020 varied between 6.7 and 9.3 ha but decreased to 3.4 ha in 2021. Volunteers noted that the 2021 area does not represent the maximum extent. The kelp bed was observed to be larger during a September 2021 survey than earlier in the summer, but the data was lost due to GPS malfunction. Classified as *no trend* because the long-term trend regression was not significant (p = 0.26). The *no trend* classification is supported by the underestimation of extent in 2021 and by volunteer notes that the protocol threshold did not always capture the sparse kelp on the north end of the bed.

Clallam Bay

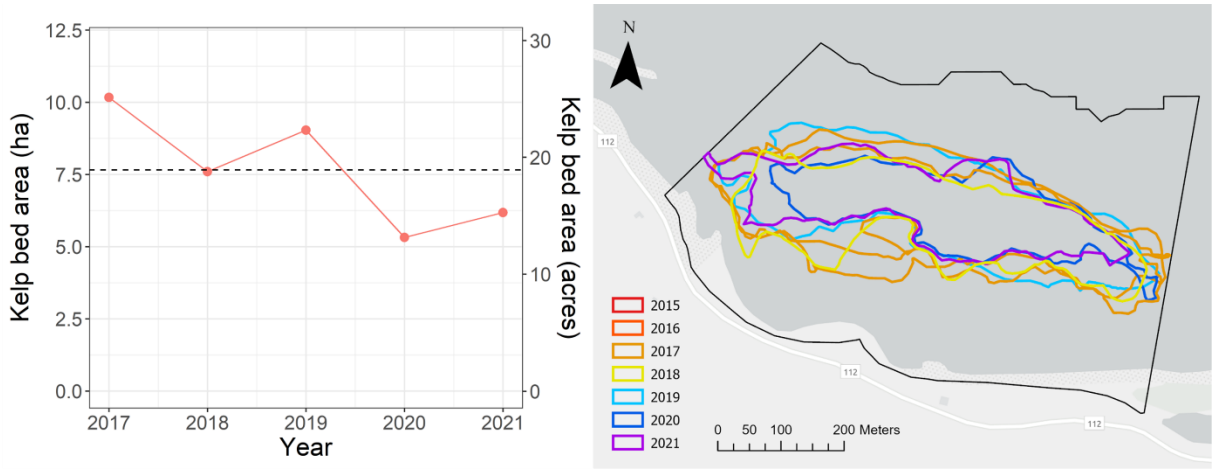


Figure 3. Clallam Bay graph of maximum bed area per year with long term mean (dashed line) and map of corresponding survey perimeters. Black polygon in map represents site extent. The overall area varied year to year, from 10.2 ha in 2017 to 6.2 ha in 2021. Classified as *no trend* because the long-term regression was not significant (p = 0.21). Additionally, volunteers identified that the mapped area was affected by environmental conditions.

Coffin Rocks

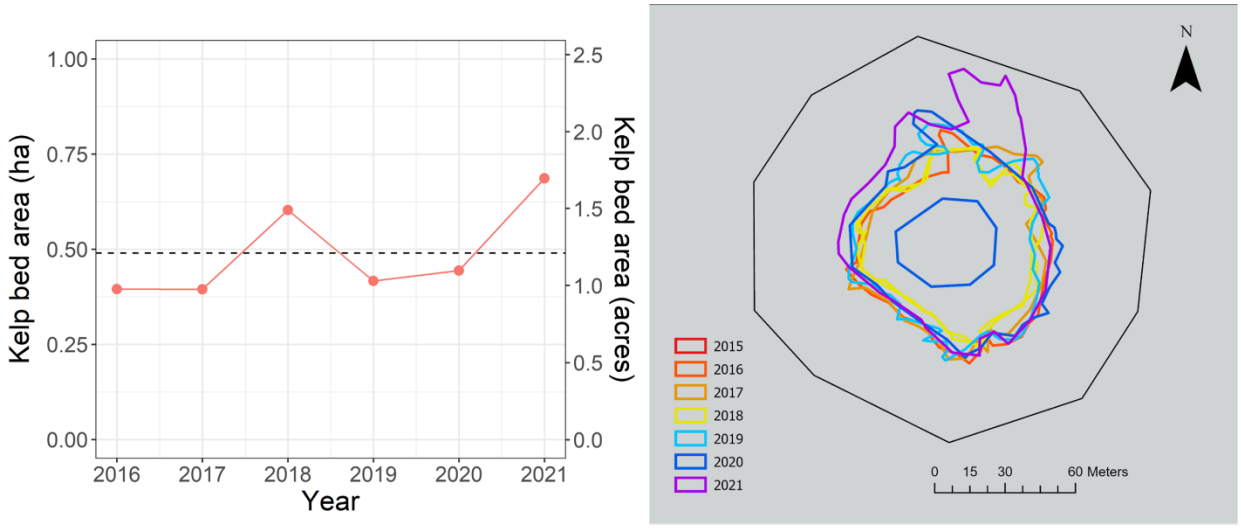


Figure 4. Coffin Rocks graph of maximum bed area per year with long term mean (dashed line) and map of corresponding survey perimeters. Black polygon in map represents site extent. Bed area increased slightly between 2016 and 2021. Volunteers observed that the expansion of kelp off the rocks on the north side of the bed has been variable between years (2020 vs. 2021). They also noted that while the perimeter varies little, the kelp density within the bed is variable. Classified as *no trend* because the long-term regression was not significant (p = 0.90).

Ebey's Landing

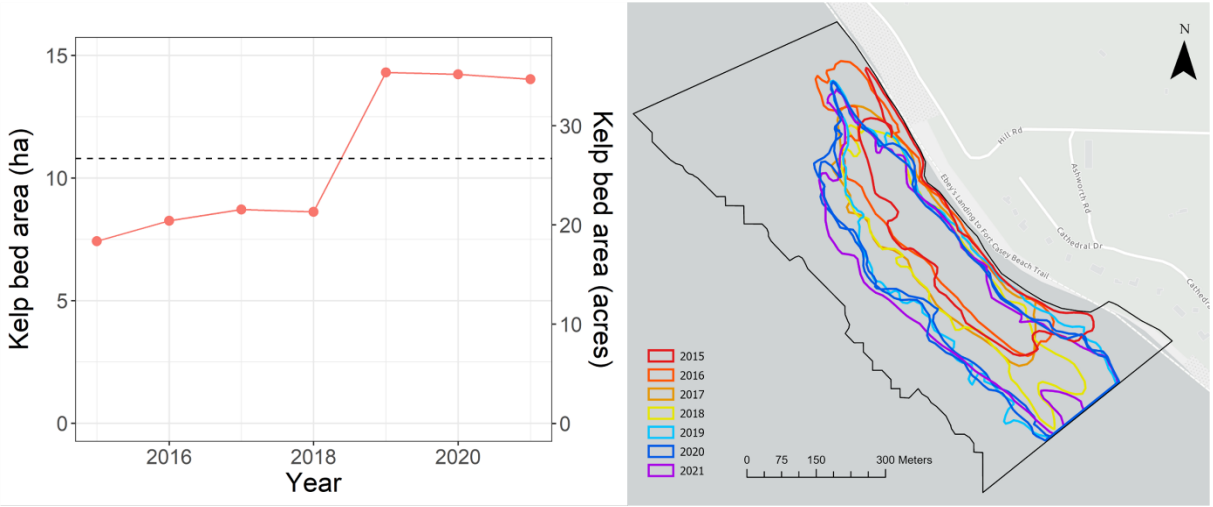


Figure 5. Ebey's Landing graph of maximum bed area per year with long term mean (dashed line) and map of corresponding survey perimeters. Black polygon in map represents site extent. Bed area was consistent from 2015-2018 then expanded in size in 2019 and has persisted at that size since. Classified as *increasing* because the long-term regression results showed a significant increase in bed area (slope = 1.334, p = 0.007). This increase is supported by volunteer observations that the bed expanded into deeper water and extended further south, merging with a kelp bed to the southeast.

Edmonds Dive Park

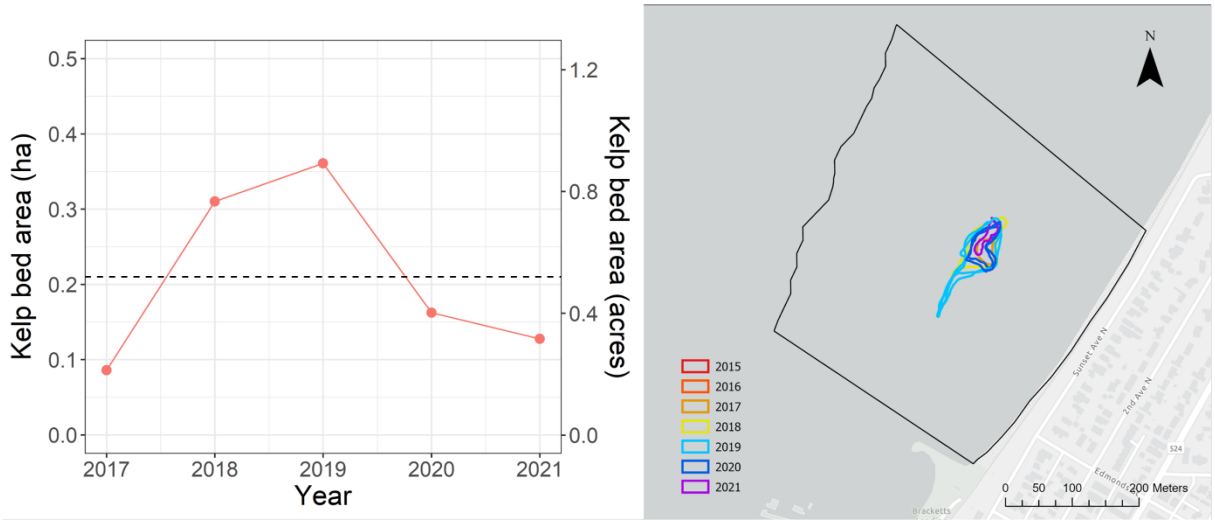


Figure 6. Edmonds Dive Park graph of maximum bed area per year with long term mean (dashed line) and map of corresponding survey perimeters. Black polygon in map represents site extent. The bed area is variable and grew from 0.1 ha in 2017 to 0.4 ha in 2019 before contracting to 0.1 ha in 2021. Classified as *no trend* because the long-term trend regression was not significant (p = 0.99).

Edmonds North

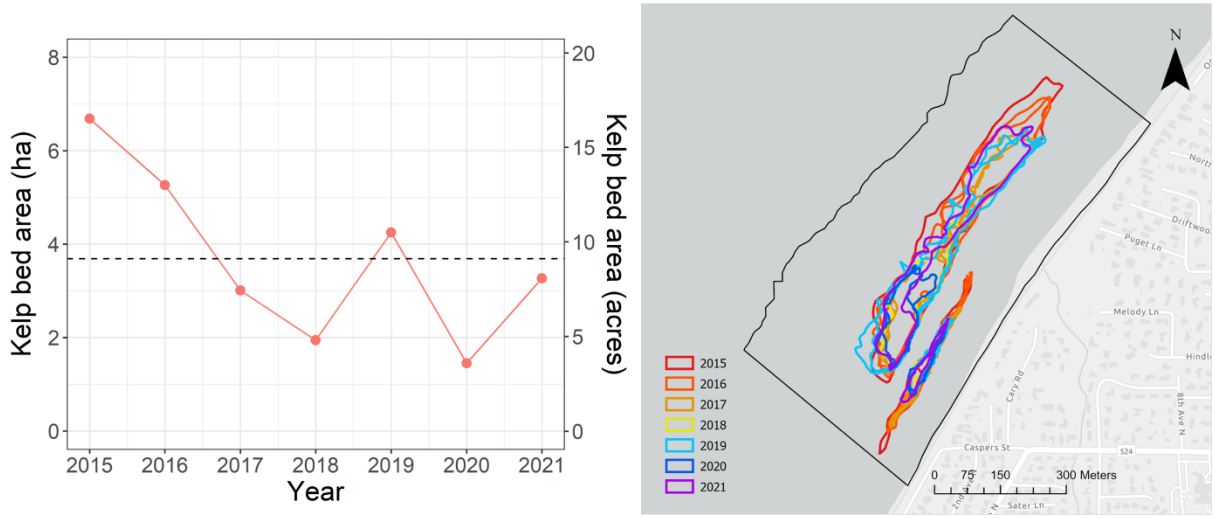


Figure 7. Edmonds North graph of maximum bed area per year with long term mean (dashed line) and map of corresponding survey perimeters. Black polygon in map represents site extent. The bed area declined from 6.7 ha in 2015 to 1.9 ha in 2018 and has been variable since. There is a decent amount of noise but both the shallow and deep kelp beds have contracted on the north and south sides. Classified as *no trend* because the long-term trend regression was not significant (p = 0.22). However, after a steep decline, the bed has fluctuated between 4.2 and 1.4 ha and additional data could change the classification.

Freshwater Bay

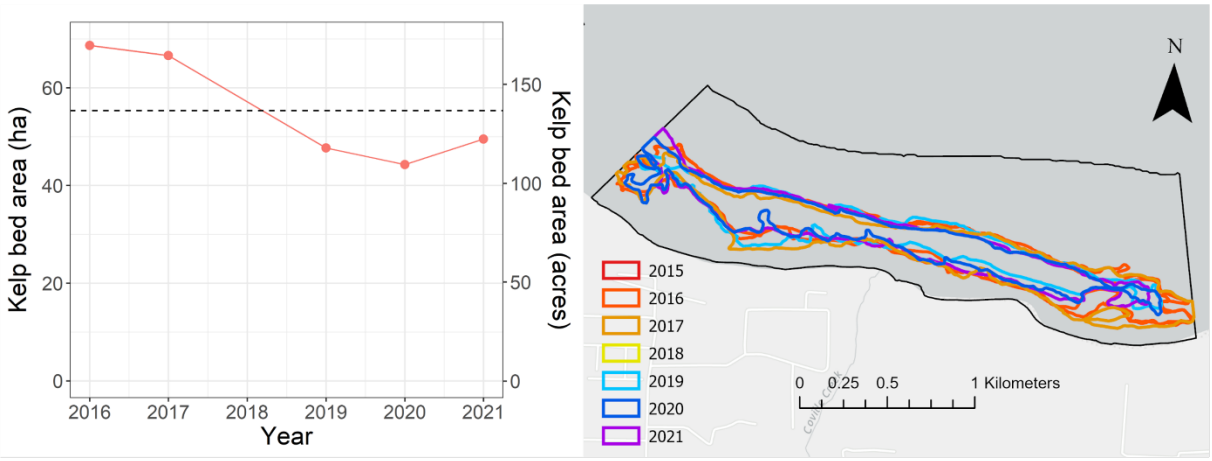


Figure 8. Freshwater Bay graph of maximum bed area per year with long term mean (dashed line) and map of corresponding survey perimeters. Black polygon in map represents site extent. Bed area decreased slightly between 2017 and 2019 from 68.7 ha to 47.7 ha before stabilizing. Change in area has been concentrated on the eastern end of the bed which contracted in recent years. Classified as *decreasing* because the long-term trend regression showed a significant decline in bed area (slope = -5.0, p < 0.001). However, volunteers noted the mapped area can be affected by environmental conditions and varying kelp density.

Hat Island

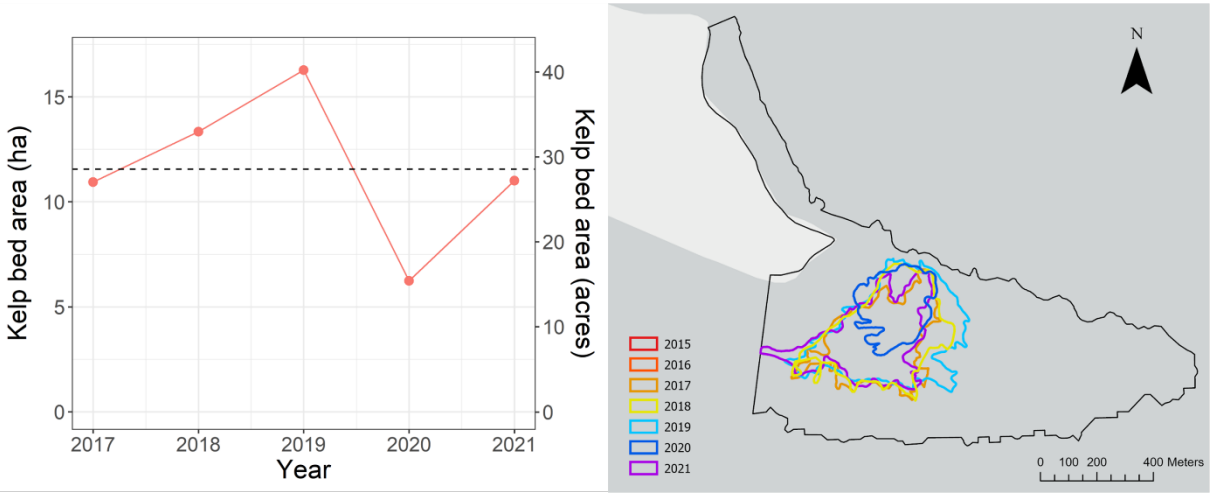


Figure 9. Hat Island graph of maximum bed area per year with long term mean (dashed line) and map of corresponding survey perimeters. Black polygon in map represents site extent. Bed area varied slightly and increased from 2017 to 2019. The bed contracted in 2020 and rebounded in 2021. Classified as *no trend* because the long-term trend regression was not significant (p = 0.39). Additionally, the Snohomish MRC noted that different boat drivers could account for some variability (survey conducted by Tulalip tribal boat from 2017-2019 and Snohomish County boat in 2020-2021).

Lummi SW

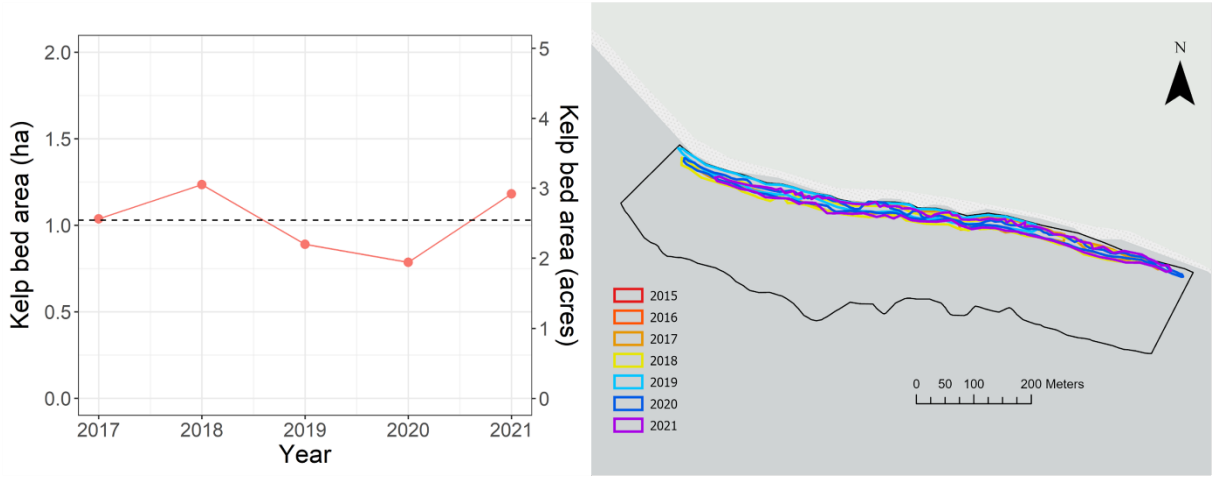


Figure 10. Lummi SW graph of maximum bed area per year with long term mean (dashed line) and map of corresponding survey perimeters. Black polygon in map represents site extent. Bed area fluctuated slightly between 2017 and 2021. Classified as *no trend* because the long-term trend regression was not significant (p = 0.98). The kelp bed area has been generally stable across the survey period, but volunteers noted that the shoreward edge can be tricky to map because of rocks, which could account for some of the variability.

Meadowdale

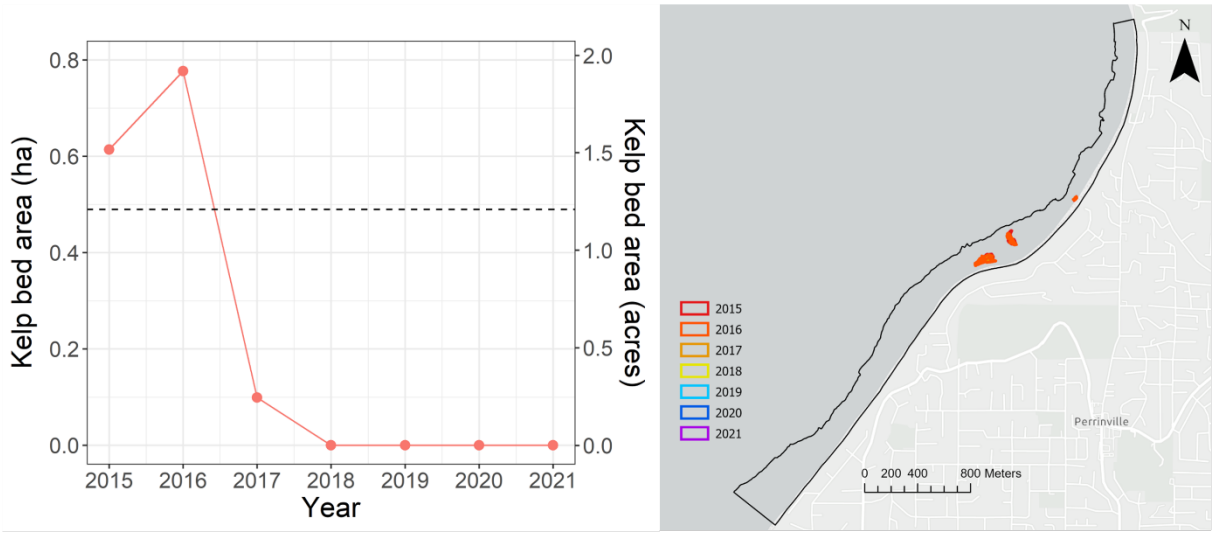


Figure 11. Meadowdale graph of maximum bed area per year with long term mean (dashed line) and map of corresponding survey perimeters. Black polygon in map represents site extent. The bed area declined from 0.78 ha in 2016 to 0.1 ha in 2017. In 2018 and 2019 there were only scattered bulbs that did not meet the density threshold for perimeter mapping. In 2020 and 2021 there were no kelp bulbs present. Classified as *total loss* because all kelp disappeared by 2020 and the absence has persisted.

Mukilteo

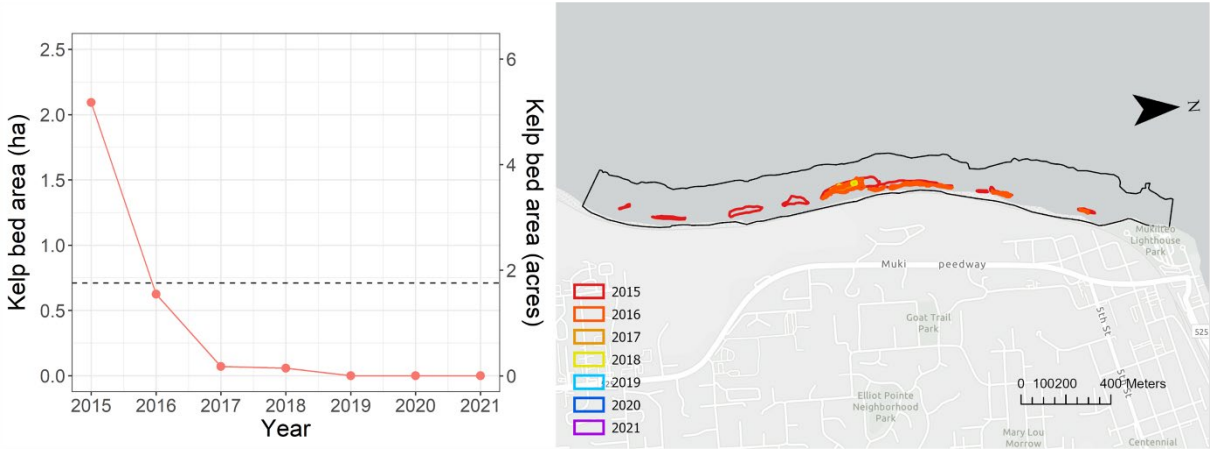


Figure 12. Mukilteo graph of maximum bed area per year with long term mean (dashed line) and map of corresponding survey perimeters. Black polygon in map represents site extent. The bed area decreased from 2.1 ha in 2015 to 0.06 ha in 2018. In 2019 there were only scattered bulbs that did not meet the threshold density for perimeter mapping and in 2020 and 2021 there were no kelp bulbs present. Classified as *total loss* because all kelp as disappeared by 2020 and the absence has persisted.

North Beach Main

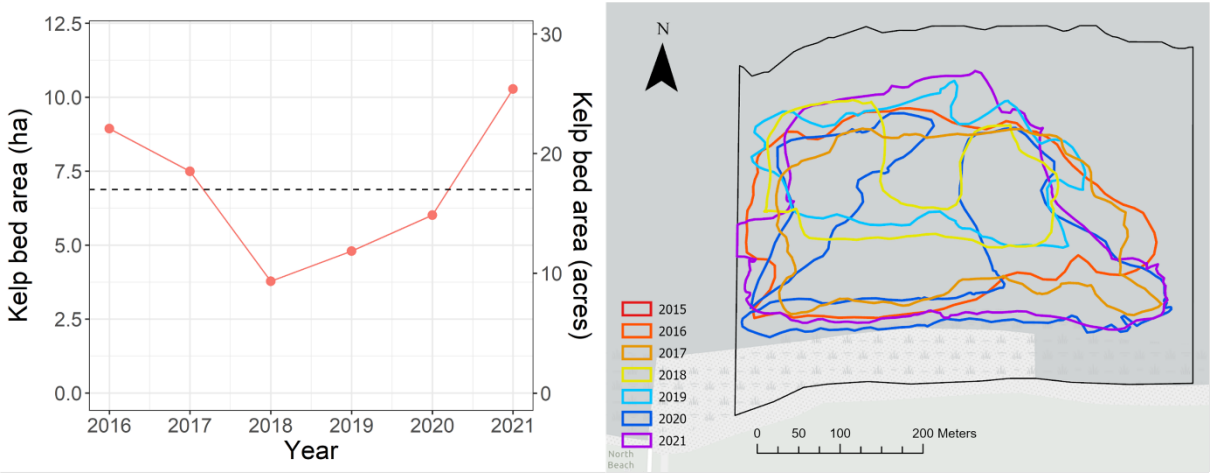


Figure 13. North Beach Main graph of maximum bed area per year with long term mean (dashed line) and map of corresponding survey perimeters. Black polygon in map represents site extent. The bed was variable in both area and footprint. Area decreased between 2016 and 2018 before increasing to 10.3 ha in 2021. Volunteers reported low density floating kelp occurred outside the mapped perimeter. Classified as *no trend* because the long-term trend regression was not significant (p = 0.88). However, minor changes in bed footprint could be due to the density threshold that is used to determine bed extent.

Observatory Point

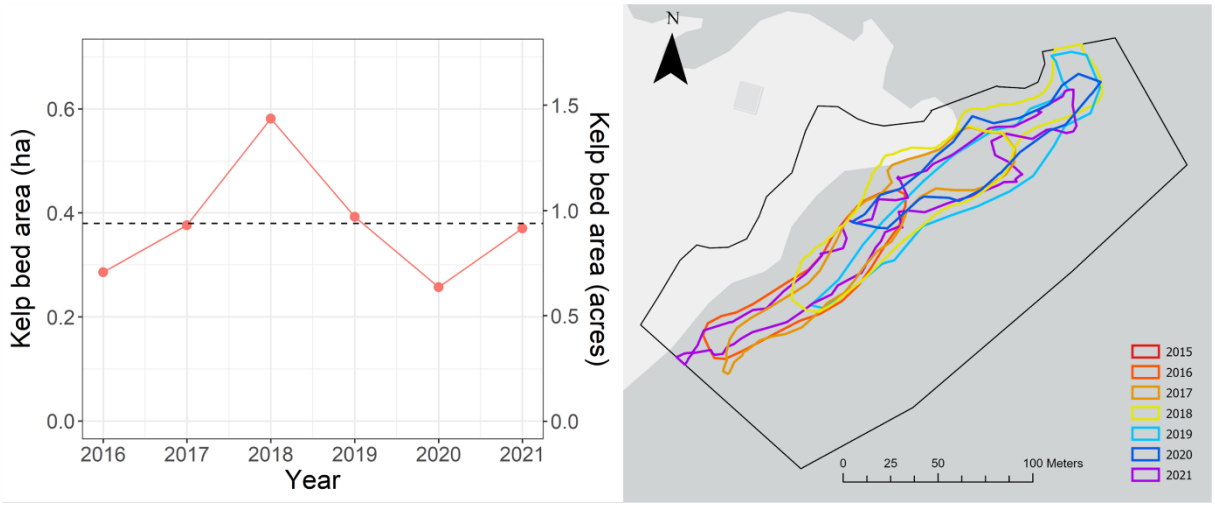


Figure 14. Observatory Point graph of maximum bed area per year with long term mean (dashed line) and map of corresponding survey perimeters. Black polygon in map represents site extent. The bed area and footprint varied slightly year to year. The bed increased to 0.6 ha in 2018 before declining slightly but it has returned to the long-term mean. Classified as *no trend* because the long-term trend regression was not significant (p = 0.99).

Polnell Point

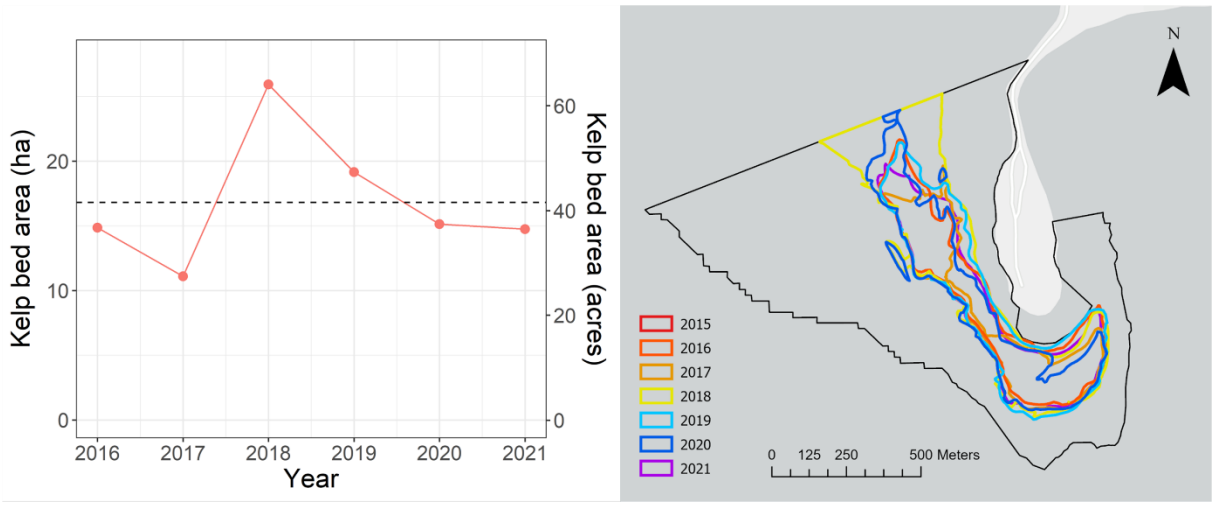


Figure 15. Polnell Point graph of maximum bed area per year with long term mean (dashed line) and map of corresponding survey perimeters. Black polygon in map represents site extent. Bed area has fluctuated between 11.1 ha and 25.9 ha but has seen no dramatic overall directional changes. Each year, the bed starts out as several discrete beds before merging into one bed later in the growing season. Classified as *no trend* because the long-term trend regression was not significant (p = 0.83). Kelp bed area has been generally stable across the survey period and volunteers have noted most of the variation is concentrated in the northwestern portion of the bed, where there is sparse kelp that doesn't always meet the threshold for perimeter mapping.

Possession Point

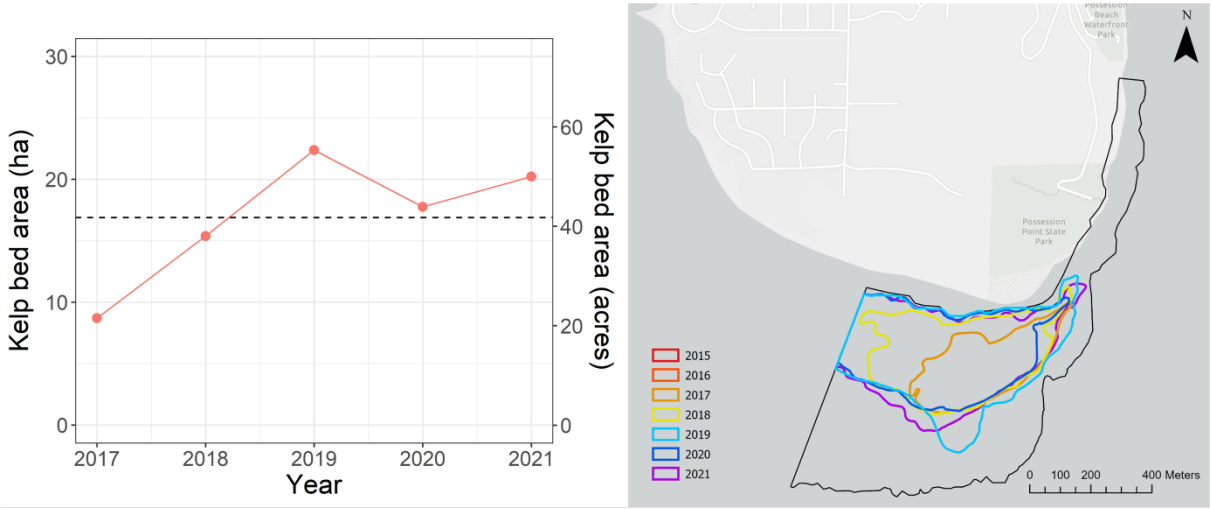


Figure 16. Possession Point graph of maximum bed area per year with long term mean (dashed line) and map of corresponding survey perimeters. Black polygon in map represents site extent. Bed area increased from 8.7 ha in 2017 to 22.4 ha in 2019 and has persisted at the higher level. The bed expanded to the west and volunteers observed that it merged with a kelp bed on the west side of the point in 2019. Classified as *increasing* because the long-term trend regression showed a significant increase in bed area (slope = 2.5, p = 0.002). The regression results are supported by the consistent bed expansion and eventual merge with another bed.

Shannon Point East

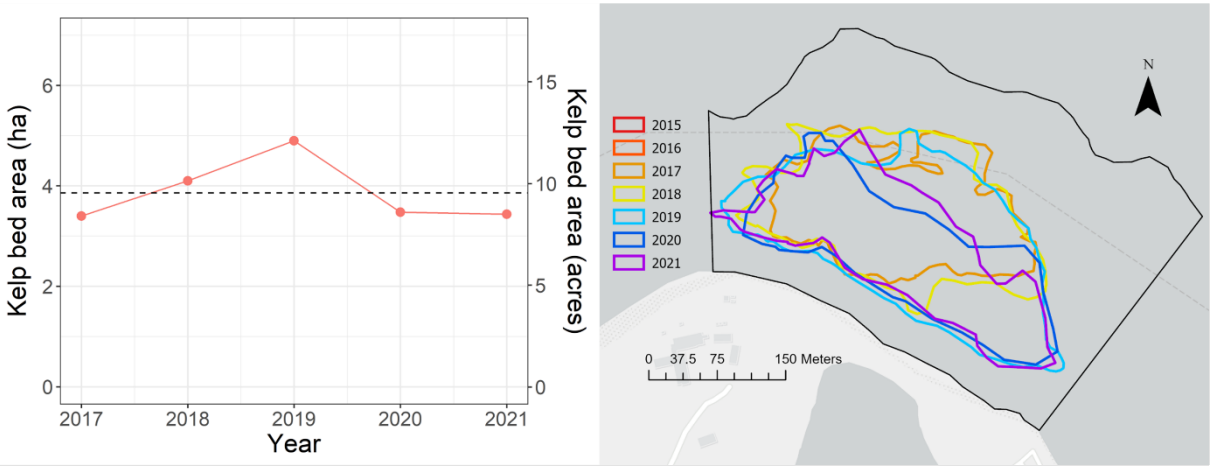


Figure 17. Shannon Point East graph of maximum bed area per year with long term mean (dashed line) and map of corresponding survey perimeters. Black polygon in map represents site extent. The bed area has varied slightly, the largest area was 4.9 ha in 2019. Classified as *no trend* because the long-term trend regression was not significant (p = 0.94). While there has been little change in area, volunteers have noted that currents can make mapping challenging, which could account for some variability.

Shannon Point West

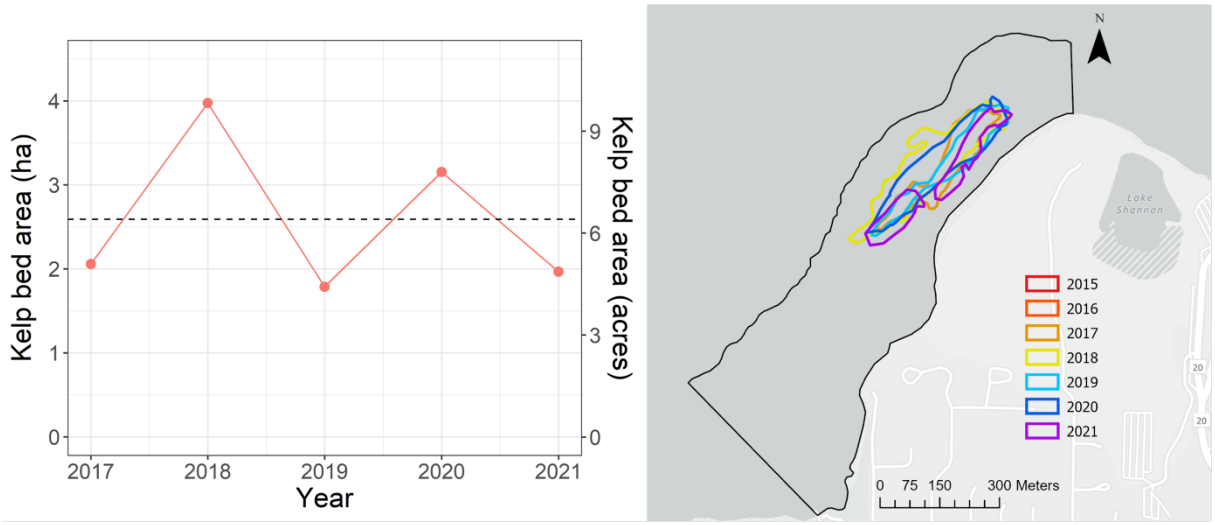


Figure 18. Shannon Point West graph of maximum bed area per year with long term mean (dashed line) and map of corresponding survey perimeters. Black polygon in map represents site extent. The bed area has fluctuated year to year, with larger areas in 2018 and 2020 (4.0 and 3.2 ha respectively) and smaller areas in 2019 and 2021 (1.8 and 1.9 ha respectively). Classified as *no trend* because the long-term trend regression was not significant (p = 0.90). However, volunteers noted that sparse kelp often trails off the west edge of the bed and doesn't always meet the threshold density for perimeter mapping, which could affect the mapped area.

Appendix 2: Survey notes addressing mapping and threshold challenges

Challenge	Survey notes and observations recorded on field datasheets and other recollections from surveyors
Wind	"West wind and swells made it hard to stay stationary"
	"Windy conditions. The edge of the bed was not well defined and the wind make it difficult to trace. Downwind turns (to the east) were wide and added about 10 m to the edge of the bed"
	"10-15kts of wind made survey difficult. Wind and current made us drift east quickly if we stopped paddling"
	"Wind and sea conditions limited visibility beneath the surface. S winds from 5kts building to 12kts. Could not complete all depth/temp measurements due to deteriorating conditions"
	"It was windy also and hard to closely follow bed"
	"Windier with slight swell – in the "iffy" zone to survey-harder to see bulbs"
	"Wave ripples making kelp somewhat hard to see"
	"Some kelp bulbs underwater due to wind-driven surface current even though tide currents were slack. If bulbs not submerged, bed would be bigger"
	"Wind, occasionally gusting 10-15kts made all aspects of the survey harder and results more suspect than usual"
	"In 2020 we had sudden weather-related reasons to rush the second half of the survey, avoid rocks, and avoid waves, so the outline is actually intentionally smaller than the kelp bed genuinely was. This is revealed only in the notes about the survey, but not reflected in the final image of the footprint of the bed."
Current	"Current switch form about 1kt to 2kt flood during survey, making ToBe for bed 3 very tricky. One might consider doing Shannon point at zero tide (always big currents) as opposed to higher tide with less current change"
	"Current was too strong and affected perimeter and was too strong for depth"
	"Current going strong west but back eddies once through pass. Tough to be accurate"
	"A lot of current at zero tide made determining bed size a little tricky"
	"Strong ebb current at zero tide-many kelp submerged making bed extent determination difficult"
	"Slack current using deep zoom predicted at 11:55. We found strong incoming current at 11:15. Made for difficult measurements"
Visibility	"Water visibility poor"
	"Very low visibility made it difficult to know the perspectives of the photos"

	"Too foggy/dark to see depth or understory"
Threshold density	"Kelp is dense in the outer patch and in the inner fringing patch. Sparse bulbs in between made determining the boundary difficult, especially as the tide came in"
	"Bed massive but some areas sparse and based on protocol decided not to record in perimeter of actual bed. (Notes on map: Kelp definitely continues but very sparse so decision made to call edge of bed. Made another decision to cut out sparse individuals connecting shoreline bed)"
	"Diffuse kelp between beds 2 and 3 marked with WP 5 (bed btw 2&3). Not dense (yet? Next month?)"
	"Were a little unsure how many scattered bulbs to take readings on"
	"Edge was not well defined. There were individual kelp plants all the way to North Beach East"
	"Not confident of perimeter at north/deepest edge of bed since there were many small bulbs and we were not sure if they were attached"
	"Edge of bed difficult to distinguish in places, because the kelp was so spread out along the edges"
	"The edge of the bed was not well defined, and the wind made it difficult to trace"

Appendix 3: MRC Indicator Dataset Description

Data Review

For an initial review, DNR assessed each survey perimeter at 18 priority sites and compiled review questions, on both the individual surveys and the sites in general. DNR then met with small groups of volunteers from each MRC to discuss each survey and site to gain insights into site and survey conditions, methods, and uncertainties about the data. There were also discussions about surveys that seemed anomalous compared to the other surveys collected and whether to exclude the surveys from inclusion in the vital sign and analyses. In each meeting, MRC volunteers and DNR worked to delineate a "survey extent" for each site, defined as the area that had been consistently surveyed for floating kelp each year. Defining survey extents was important in determining which surveys could be directly compared, and which surveys needed to be cropped or excluded from multiyear comparisons.

The goal of creating survey extents was to identify the consistently sampled area and use the extent to generate a subset of data with comparable survey perimeters. For example, when surveys at Possession Point began, there were two distinct kelp beds, one on the east side of the point and one on the west, and volunteers only mapped the east bed. However, starting in 2019, the east and west beds merged and were subsequently mapped as one bed. Because the western end of the merged bed was not surveyed every year (before 2019), the Indicator survey extent ends at the maximum extent of the 2018 survey so all years are comparable (Figure 1). The survey extent was then used to clip the data within it for inclusion in the Indicator dataset, while the portions of the perimeters outside the survey extent (dashed lines in Figure 1) were excluded.

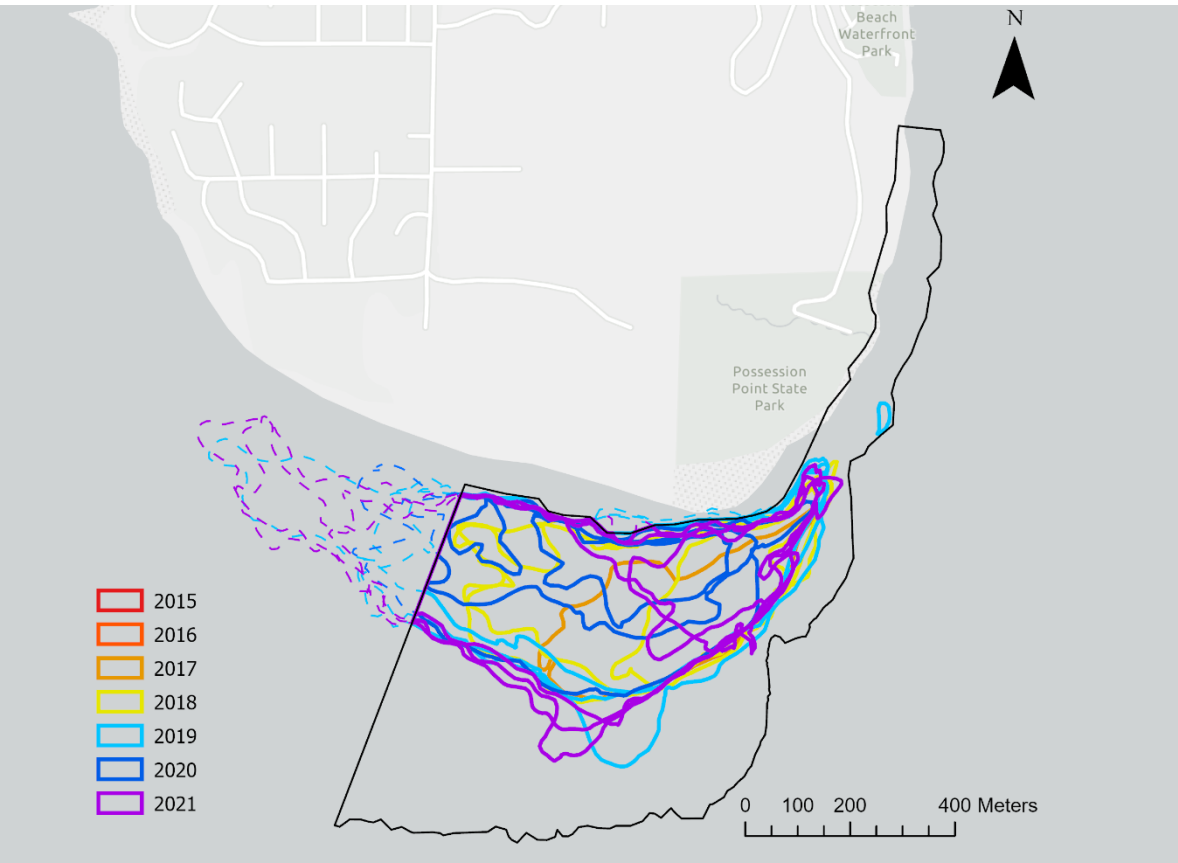


Figure 1. Possession Point survey lines included in the Indicator dataset (solid lines) within the defined site extent (black line). Dashed lines represent survey area that was excluded from the Indicator dataset.

After meeting with individual MRCs, the survey extents were refined and sent to the volunteers for final confirmation of the accuracy of the alongshore extent. At some sites, multiple kelp beds were included in one survey extent and at others, multiple kelp beds were split into separate survey extents (Table 1). The survey extents were used to create a polygon feature class in ArcGIS Pro, and the features were added to the DNR working database and used to clip comparable data out of the full MRC dataset to include in the Indicator dataset (see database structure section below).

Data processing and description of database structures

Figure 2 provides a visual of how data flows from collection by MRC volunteers, ingestion to the online webform KoboToolbox, to NW Straits data processing, and on to DNRs working database, and finally to the Vital Sign database process. Not captured in the visual, but critical to this community science effort is the iterative process of data cleaning and verification with volunteers each survey season to confirm if final data accurately reflects field observations.

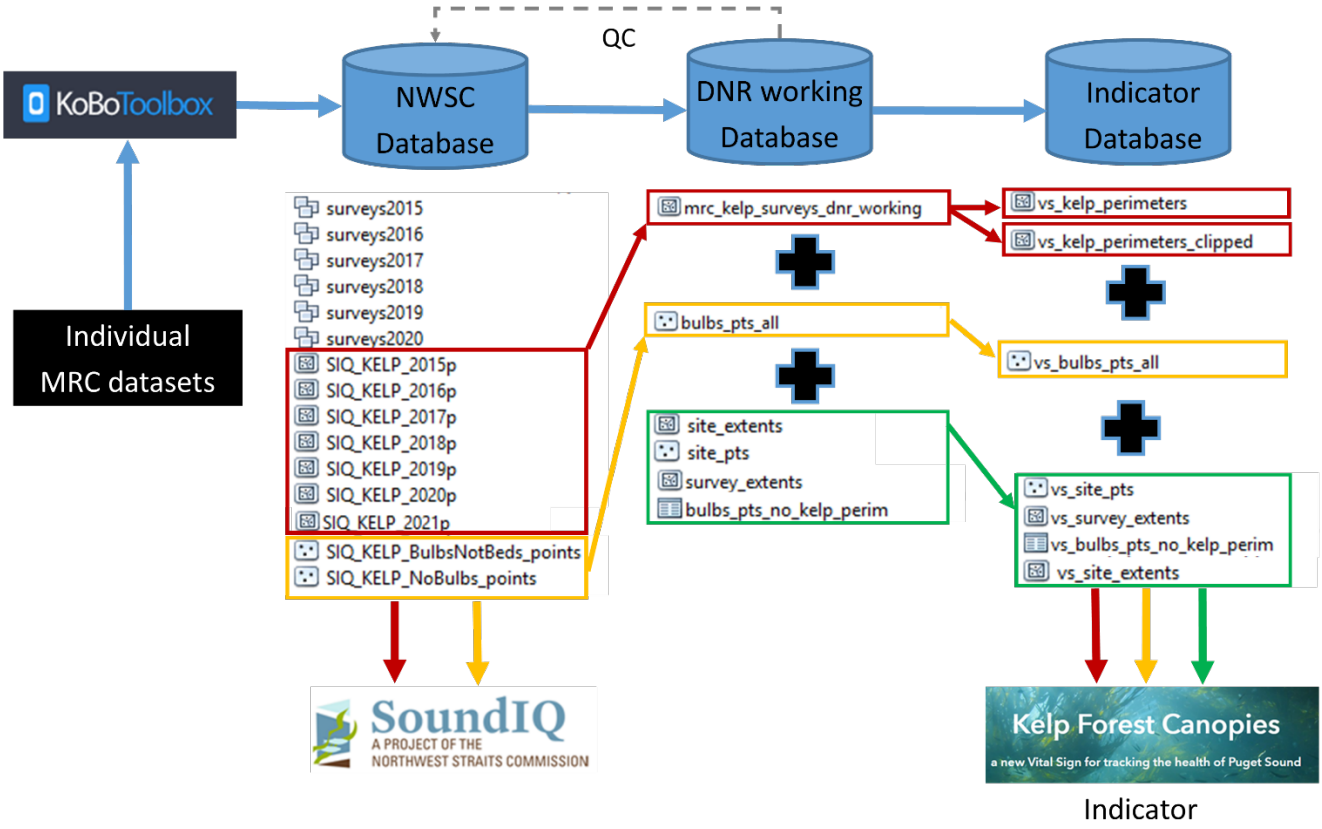


Figure 2. Flow chart of MRC kelp dataset from field collection to Indicator database

Northwest Straits Commission Database

The data collected by MRC volunteers includes floating kelp perimeter data, field datasheet information and photos. Volunteers upload data to a KoboToolbox database. Data are downloaded from KoboToolbox, cleaned, converted from GPS track points to polygons, attributed with the field data, and formatted by the Northwest Straits Commission (NWSC) to create a geodatabase for publishing to NWSC mapping application SoundIQ. The NWSC geodatabase includes:

1. A feature dataset for each year (e.g., surveys2015). Each feature dataset contains a set of kelp perimeters (polygon feature classes) that include a polygon feature for each location and survey date (e.g., Ebeys_Landing_Aug_15_2015).
2. Annual polygon features that include all kelp perimeter features merged by year (e.g., SIQ_KELP_2015p).
3. Two point feature classes:
   a. SIQ_KELP_BulbsNotBeds_points includes point features where no conspicuous bed was present but individual bulbs were found.
   b. SIQ_KELP_NoBulbs includes point features where kelp was absent (no bulbs or beds present).

DNR Working Database

In the DNR working database, the NWSC database was restructured, refined, and merged for manipulation, analysis, and visualization. New feature classes were also added in the DNR database to better define sites and survey areas.

From the NWSC database, all the annual polygon features (e.g., SIQ_KELP_2015p) were merged into a single feature class (i.e., mrc_kelp_surveys_dnr_working) and all the existing fields were retained (Table 2). After 2021, the annual features should be appended to the master mrc_kelp_surveys_dnr_working feature class. Additional fields were added to standardize the formatting and allow for easy grouping (Table 3).

The two point feature classes in the NWSC database, SIQ_KELP_BulbsNotBed and SIQ_KELP_NoBulbs, had attribute tables with different formats and field types. The attribute tables for each feature class were exported to .csv files and read into R where two attribute tables were reformatted to match each other and subsequently merged to create a single table, bulb_pts_all. A new field was added (kelp_obs) to distinguish points with no kelp from points with bulbs. The bulb_pts_all table is a record of every waypoint taken for bulbs and no bulbs and includes instances with duplicate site_code/svy_date when multiple points were taken (Table 4). A feature class was created from the table using stored coordinate information.

A second bulb point table was created by identifying surveys with no associated kelp perimeters recorded at a site (i.e., only individual bulbs found) (Table 5). This second table, bulb_pts_no_kelp_perim, is exclusive from the kelp perimeter data and contains one record for each site and survey date that had either no kelp or only bulbs present without any corresponding perimeter, representing zero acres of kelp. It can be merged with the attribute table of the kelp perimeter feature class to produce a full dataset for analysis. The table was imported in a file geodatabase in ArcGIS Pro as a table with no spatial component.

There are three additional feature classes in the DNR geodatabase that are not part of the NWSC database: site_extents, site_points, and survey_extents. Site_extents is a polygon feature created for each bed mapped by the MRC volunteers. The polygon is broad and fully encompasses all surveys conducted in a given area (Table 6). The site polygons are not standardized and range in size depending on the surveyed areas. Site_pts is a point feature derived by converting each site_extent feature to a point on the centroid of the site_extent polygon (Table 7). Survey_extents are polygon features that identify the area of each site that was consistently mapped each year (Table 8). The polygons were defined and made in consultation with MRC volunteers that have knowledge of survey methods and characteristics. For each site, survey_extent polygons are used to clip mapped perimeters to a common extent.

Indicator Database

The Indicator database is populated by executing a Python script that references the DNR working database. The only feature class that underwent structural changes to the tabular data was vs_kelp_perimeters. All other tables and feature classes were copied to the vital sign database and renamed (vs_survey_extents, vs_site_extents, vs_site_pts, vs_bulb_pts_all, vs_bulb_pts_no_kelp_perim).

To create the vs_kelp_perimeters feature class the Python script copied the features from the dnr_working_db and then formatted the survey data in the following ways: (1) executed a

spatial join to site_pts to relate a site_code to each perimeter, (2) executed a spatial join to site_extents to relate site_extent value to each perimeter, (3) deleted nonessential fields to streamline dataset, (4) added and populated a kelp_acreage field, and (5) reordered fields. The output of this script was the vs_kelp_perimeters polygon feature class (Table 9). To isolate only the surveys suitable for inclusion in the vital sign, the vs_kelp_perimeters feature class was then clipped to a corresponding vs_survey_extents feature to create vs_kelp_perimeters_clipped feature class. Only perimeters within the vs_survey_extent polygons and suitable for analysis were used to populate the vs_kelp_perimeters_clipped feature class.

Table 1. MRC kelp bed names for the sites in the initial Indicator review and corresponding Indicator site names assigned to each bed.

MRC Kelp Bed Name	Indicator Site Name
Biz Point	Biz Point
Cherry Point-Gulf Rd	Cherry Point
Clallam Bay	Clallam Bay
Coffin Rocks	Coffin Rocks
Ebey's Landing	Ebey's Landing
Edmonds 1	Edmonds Dive Park
Edmonds 2	Edmonds North
Edmonds 3	Edmonds North
Freshwater Bay 1	Freshwater Bay
Freshwater Bay 2	Observatory Point
Hat Island	Hat Island
Lummi SW	Lummi SW
Meadowdale 1 (C)	Meadowdale
Meadowdale 2 (B)	Meadowdale
Meadowdale 3 (A)	Meadowdale
Mukilteo 1 (B)	Mukilteo
Mukilteo 2&3 (D)	Mukilteo
Mukilteo 4	Mukilteo
Mukilteo 5 (E)	Mukilteo
Mukilteo 6 (A)	Mukilteo
Mukilteo C	Mukilteo

Mukilteo F	Mukilteo
Mukilteo G	Mukilteo
Mukilteo H	Mukilteo
Mukilteo I	Mukilteo
North Beach East	North Beach Main
Polnell Point	Polnell Point
Possession Point	Possession Point
Shannon Point East (1&2)	Shannon Point East
Shannon Point West (3)	Shannon Point West

Table 2. Fields retained from NWSC data in mrc_kelp_survey_dnr_working

Field name	Field type	Field description
BedName	Text	Name given to kelp bed by MRC volunteers
SurveyDate	Text	Date of survey
Acres	Double	Bed area in acres
Miles	Double	Perimeter of polygon in miles
County	Text	County survey occurred in
Location	Text	Location of kelp bed
Bulb_m2	Double	Density of bulbs per meter squared
WaTemp	Double	Water temperature (°C)
Wx	Text	Weather during survey
TideStation	Text	Tide station used to get tidal height
Obs	Text	Observations
Notes	Text	Notes
ToBe	Text	URL for photo taken of kelp bed towards the shore
ToWa	Text	URL for photo taken of kelp bed towards the water
BeL	Text	URL for photo taken of kelp bed with beach to the left
BeR	Text	URL for photo taken of kelp bed with beach to the right
CorrDepShor	Double	Corrected depth on the shore edge of the bed (m, MLLW)
CorrDepShore	Double	Corrected depth on the shore edge of the bed (m, MLLW)

CorrDepWa	Double	Corrected depth on the water edge of the bed (m, MLLW)
TidalHt_meters	Double	Tidal height in meters
TidalHt_meter	Double	Tidal height in meters
Obs2	Text	Additional observations
URL	Text	URL
WaTemp1	Double	Water Temperature (°C)
WaTemp2	Double	Water Temperature (°C)

Table 3. Standardized fields added by DNR in mrc_kelp_surveys_dnr_working

Field name	Field type	Field description
site_name	Text, Length: 20	Site name (derived from mrc bed name field)
svy_day	Short	Day of survey (derived from survey date)
svy_mon	Short	Month of survey (derived from survey date)
svy_yr	Short	Year of survey (derived from survey date)
svy_date	Text, Length: 8	Date of survey (concat DDMMYYYY)
visit_num[+]	Short	Site visit number (incrementing integer, starts at 1 year year)
svy_num[+]	Short	Survey number (incrementing integer, starts at 1 each visit)
analyze[+]	Short	Flag field used by DNR to track perimeters suitable for inclusion in analyses (0 = no, 1 = yes)
notes_dnr[+]	Text, Length: 100	Note field used by DNR

[+] = populated by DNR

Table 4. Fields in bulb_pts_all and vs_bulb_pts_all

Field name	Field type	Field description
BedNameMRC	Text, Length: 25	MRC Bed Name
site_code[+]	Text, Length: 8	Unique code used to identify sites (DNR)
svy_date	Text, Length: 8	Day of survey (derived from survey date)
svy_yr	Short	Year of survey (derived from survey date)
svy_mon	Short	Month of survey (derived from survey date)

svy_day	Short	Day of survey (derived from survey date)
County	Text, Length: 25	County survey occurred in
kelp_obs[+]	Text, Length: 25	Note associated with point: either ‘no bulbs’ or ‘bulbs not bed’
Lat	Double	Latitude
Lon	Double	Longitude

[+] = populated by DNR

Table 5. Fields in bulb_pts_no_kelp_perim and vs_bulb_pts_no_kelp_perim

Field name	Field type	Field description
site_code	Text, Length: 8	Unique code used to identify sites (DNR)
svy_date	Text, Length: 8	Date of survey (concat DDMMYYYY)
svy_day	Short	Day of survey (derived from survey date)
svy_mon	Short	Month of survey (derived from survey date)
svy_yr	Short	Year of survey (derived from survey date)
visit_num[+]	Short	Site visit number (incrementing integer, starts at 1 year year)
svy_num[+]	Short	Survey number (incrementing integer, starts at 1 each visit)
kelp_obs[+]	Text, Length: 25	Note associated with point: either ‘no bulbs’ or ‘bulbs not bed’
svy_area_ac	Float	Survey area in acres
site_extent[+]	Text, Length: 15	Concatenation of site_code and extent_num used to relate survey_extents to kelp_perimeters
analyze[+]	Short	Flag field used by DNR to track perimeters suitable for inclusion in analyses (0 = no, 1 = yes)
notes_dnr[+]	Text, Length: 100	Note field used by DNR

[+] = populated by DNR

Table 6. Fields in site_extent and vs_site_extent

Field name	Field type	Field description
site_code[+]	Text, Length: 8	Unique code used to identify sites (DNR)
site_location[+]	Text, Length: 25	Site location, used to provide a detailed description of site_code (DNR)
vital_sign[+]	Short	Flag field used to indicate whether or not site is a 'vital sign' site (0 = no, 1 = yes)
lat	Double	Latitude
lon	Double	Longitude

[+] = populated by DNR

Table 7. Fields in site_pts and vs_site_pts

Field name	Field type	Field description
site_code[+]	Text, Length: 8	Unique code used to identify sites (DNR)
site_location[+]	Text, Length: 25	Site location, used to provide a detailed description of site_code (DNR)
vital_sign[+]	Short	Flag field used to indicate whether or not site is a 'vital sign' site (0 = no, 1 = yes)
lat	Double	Latitude
lon	Double	Longitude

[+] = populated by DNR

Table 8. Fields in survey_extent and vs_survey_extent

Field name	Field type	Field description
site_code[+]	Text, Length: 8	Unique code used to identify sites (DNR)
site_location[+]	Text, Length: 25	Site location, used to provide a detailed description of site_code (DNR)
extent_num[+]	Short	Incrementing integer used to track and relate site_extents to a site (site_code) and survey (kelp_perimeter)
site_extent	Text, Length: 15	Concatenation of site_code and extent_num used to relate survey_extents to kelp_perimeters

[+] = populated by DNR

Table 9. Fields in vs_kelp_perimeters and vs_kelp_perimeters_clipped

Field name	Field type	Field description
site_code	Text, Length: 20	Unique code used to identify sites (DNR)
svy_date	Text, Length: 8	Date of survey (concat DDMMYYYY)
svy_day	Short	Day of survey (derived from survey date)
svy_mon	Short	Month of survey (derived from survey date)
svy_yr	Short	Year of survey (derived from survey date)
visit_num	Short	Site visit number (incrementing integer, starts at 1 year year)
svy_num	Short	Survey number (incrementing integer, starts at 1 each visit)
svy_area_ac	Float	Survey area in acres
site_extent	Text, Length: 15	Concatenation of site_code and extent_num used to relate survey_extents to kelp_perimeters
analyze	Short	Flag field used by DNR to track perimeters suitable for inclusion in analyses (0 = no, 1 = yes)
notes_dnr	Text, Length: 100	Note field used by DNR

Appendix 4: MRC Indicator Survey Extents

This appendix includes descriptions and maps of each MRC Indicator survey extent delineated with input from volunteers at each site. Indicator survey extents are used to clip mapped perimeters to a common extent. Inset map shows location of each site within Puget Sound.

Indicator Survey extent descriptions

Biz Point: The polygon extends from the standardized shoreline created by the NW Straits to the 60 ft bathymetry line and runs from the northern guide points provided by NW Straits into Telegraph Bight. The south end of the polygon extends beyond the southern guide points because kelp is expanding into Telegraph Bight.

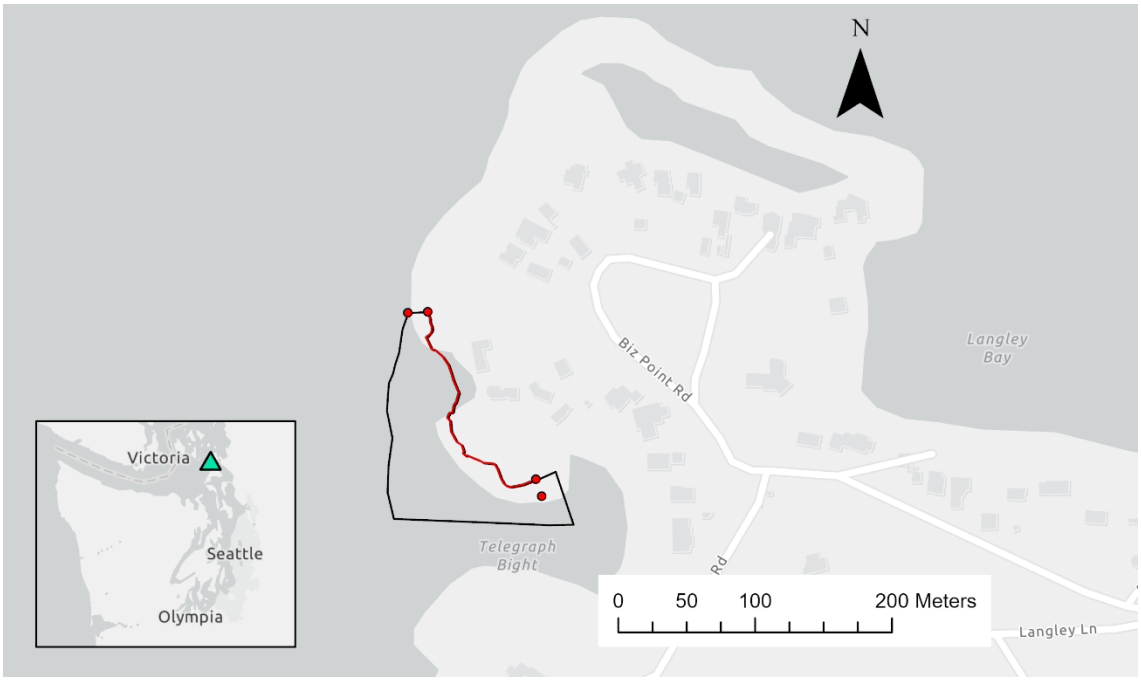


Figure 1. Biz Point Indicator survey extent (black polygon). Standardized shoreline is represented as a red line and the red dots indicate northern and southern ends of shoreline segment (minimum survey areas) created by NW Straits and Skagit County MRC.

Cherry Point: The polygon extends from the mean high tide line to the 30 ft bathymetry line. The northern boundary is the NW Straits' northern guideline, and the southern end of the polygon ends just past the maximum extent of the 2019 survey.

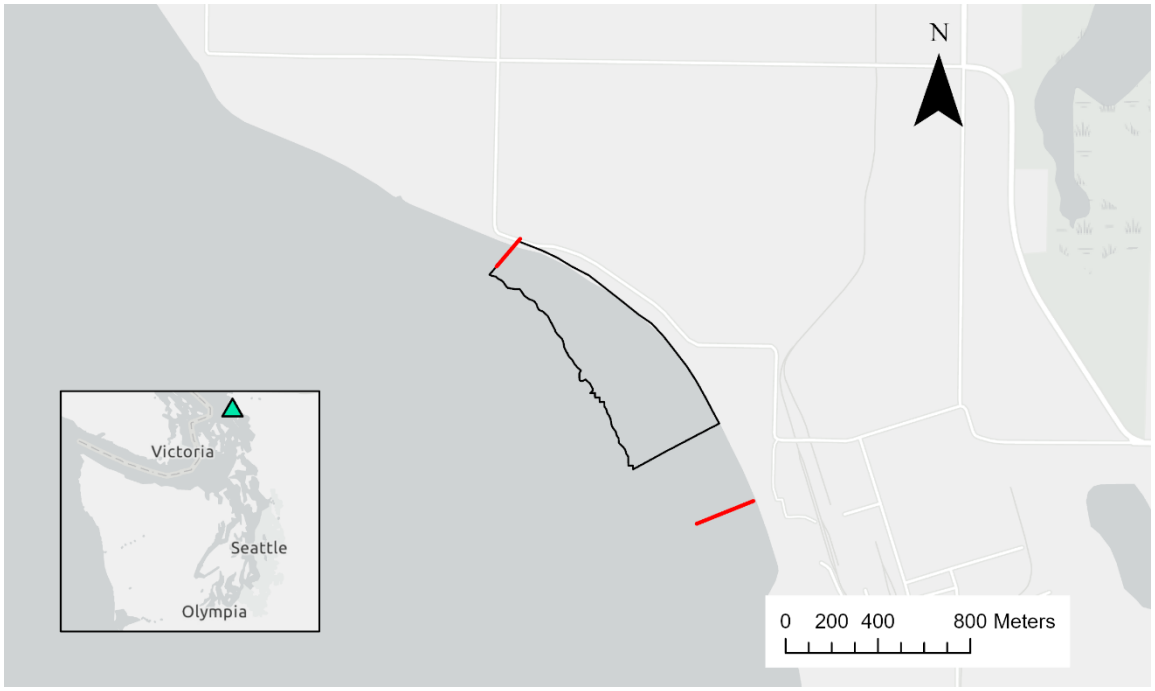


Figure 2. Cherry Point Indicator survey extent (black polygon). Red lines represent shoreline segment (minimum survey areas) created by NW Straits and Whatcom County MRC.

Clallam Bay: The polygon extends from the mean high tide line to the 30 ft bathymetry line and the NW Straits guidelines are used as the east and west polygon boundaries.

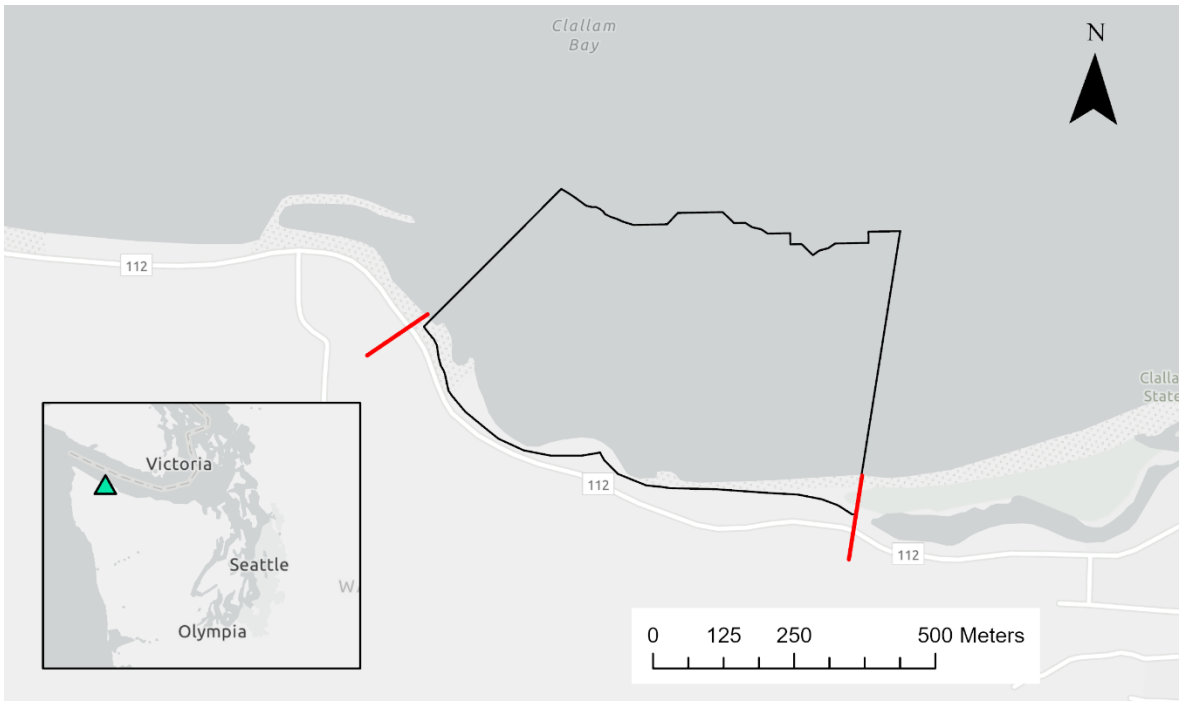


Figure 3. Clallam Bay Indicator survey extent (black polygon). Red lines represent shoreline segment (minimum survey areas) created by NW Straits and Clallam County MRC.

Coffin Rocks: Unlike site extent polygons at other sites, the polygon at Coffin Rocks does not follow any bathymetry lines or shorelines but is a large circle around the kelp bed incorporating the rock outcrop at the center.

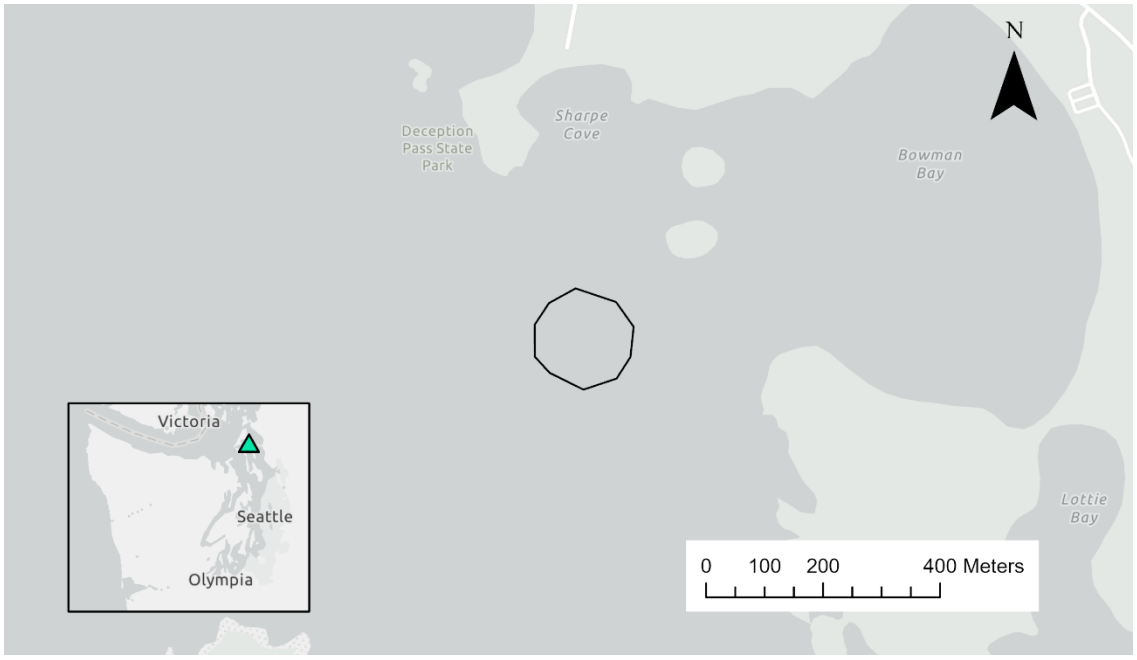


Figure 4. Coffin Rocks Indicator survey extent (black polygon).

Ebey's Landing: The polygon extends along the shoreline from the northern guideline to the maximum extent of the 2018 survey on the southern side of the bed. In 2019, 2020 and 2021, the bed grew farther to the south than in previous years and merged with another bed. For that reason, the southern end of the polygon stops at the maximum extent of the 2018 survey. The shoreward edge of the polygon closely follows the survey lines on the northern portion of the site because there are rocks and kelp in the shallows that they surveyors avoid. On the south end of the site, the shoreward polygon edge extends to the mean high tide line. The deep edge of the polygon follows the 40 ft bathymetry line.

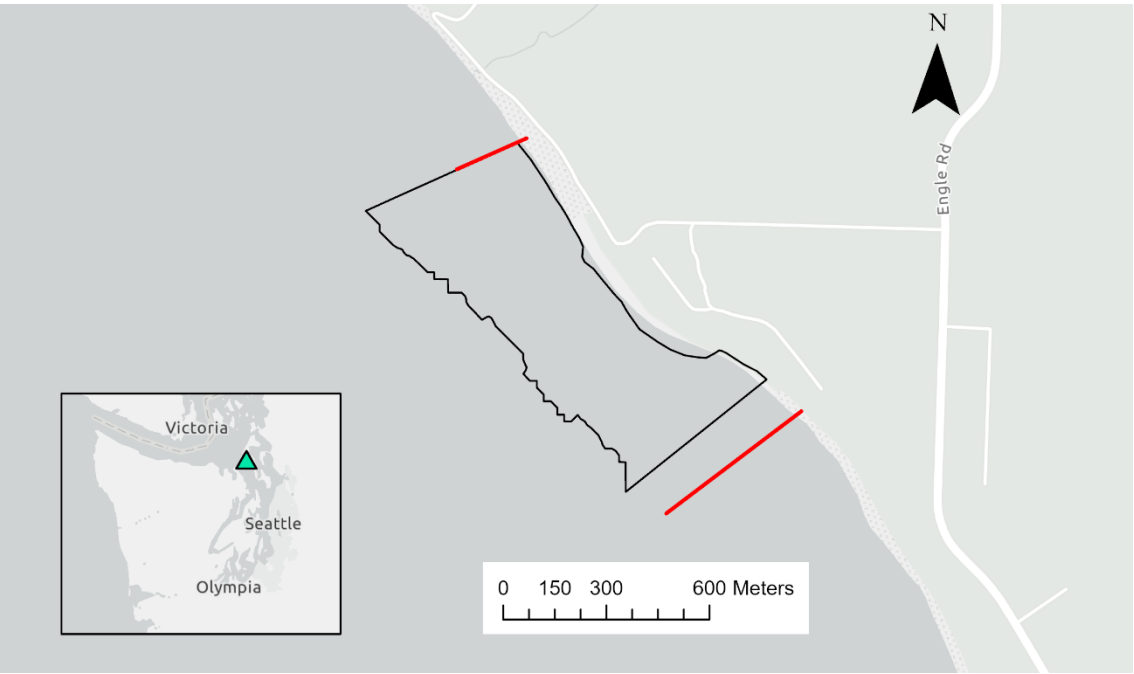


Figure 5. Ebey's Landing Indicator survey extent (black polygon). Red lines represent shoreline segment (minimum survey areas) created by NW Straits and Island County MRC.

Edmonds Dive Park: The polygon runs shoreward from the breakwater to the Edmonds North polygon and extends from the mean high tide line to the 30 ft bathymetry line. This kelp bed has a separate polygon than the two beds to the north because the Edmonds Dive Park bed has been surveyed since 2017 and the other beds have been surveyed since 2015.

Figure 6. Edmonds Dive Park Indicator survey extent (black polygon).

Edmonds North: The polygon extends from the mean high tide line to the 30 ft bathymetry line. The length (north-south) of the polygon was determined by the largest extent of the kelp beds.

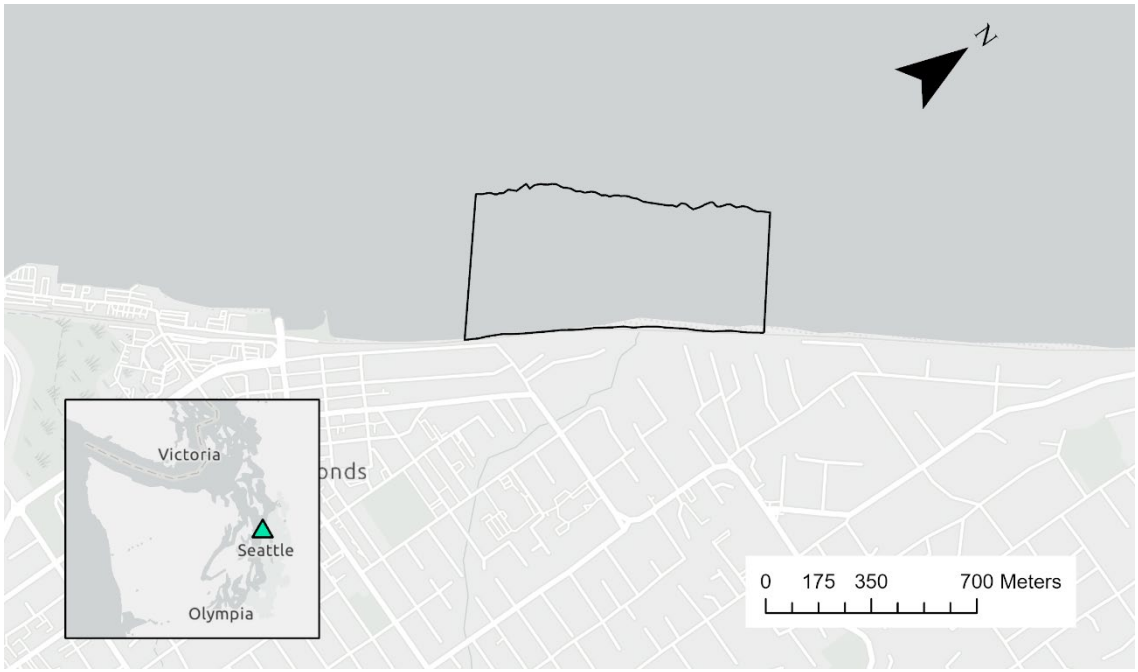


Figure 7. Edmonds North Indicator survey extent (black polygon).

Freshwater Bay: The polygon extends from the mean high tide line to the 30 ft bathymetry line and the west boundary aligns with the west NW Straits guideline and the east polygon boundary is just east of the west guideline. The 2018 survey will be excluded from the multiyear dataset because volunteers were not confident the kelp was fully mapped on the east side of the site and is therefore incomplete.

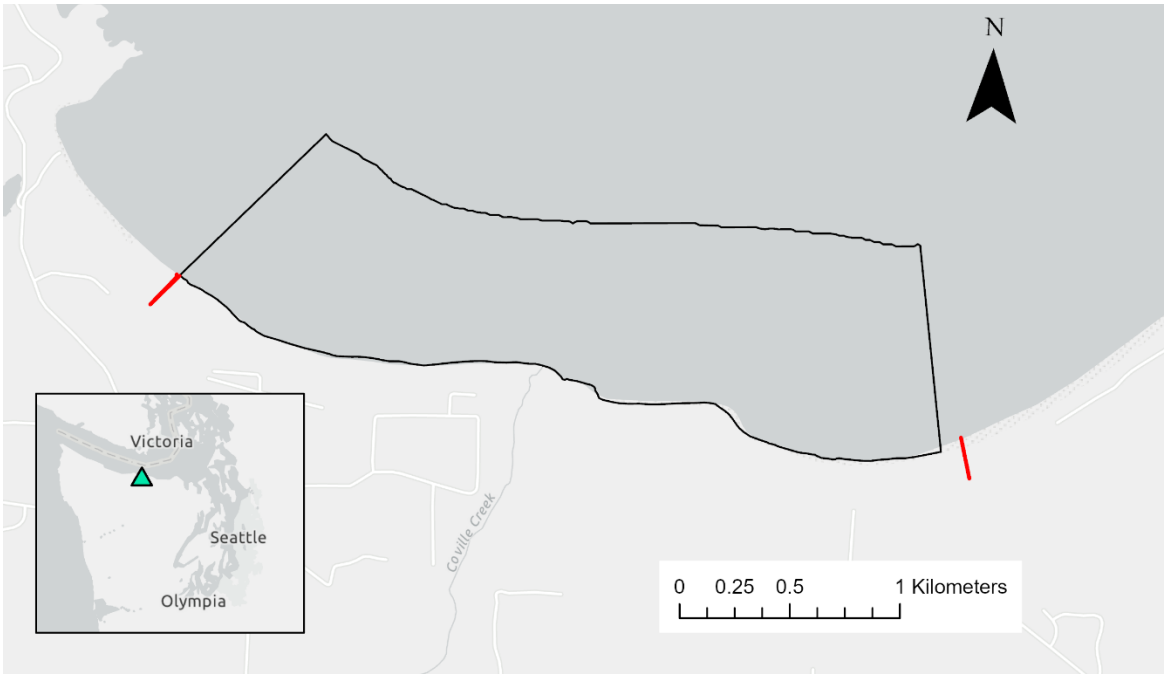


Figure 8. Freshwater Bay Indicator survey extent (black polygon). Red lines represent shoreline segment (minimum survey areas) created by NW Straits and Clallam County MRC.

Hat Island: The polygon extends from the mean high tide line to the 30 ft bathymetry line. The polygon extends up the NE side of the island to a sandy point and extends to the west just around the southern point of the island.

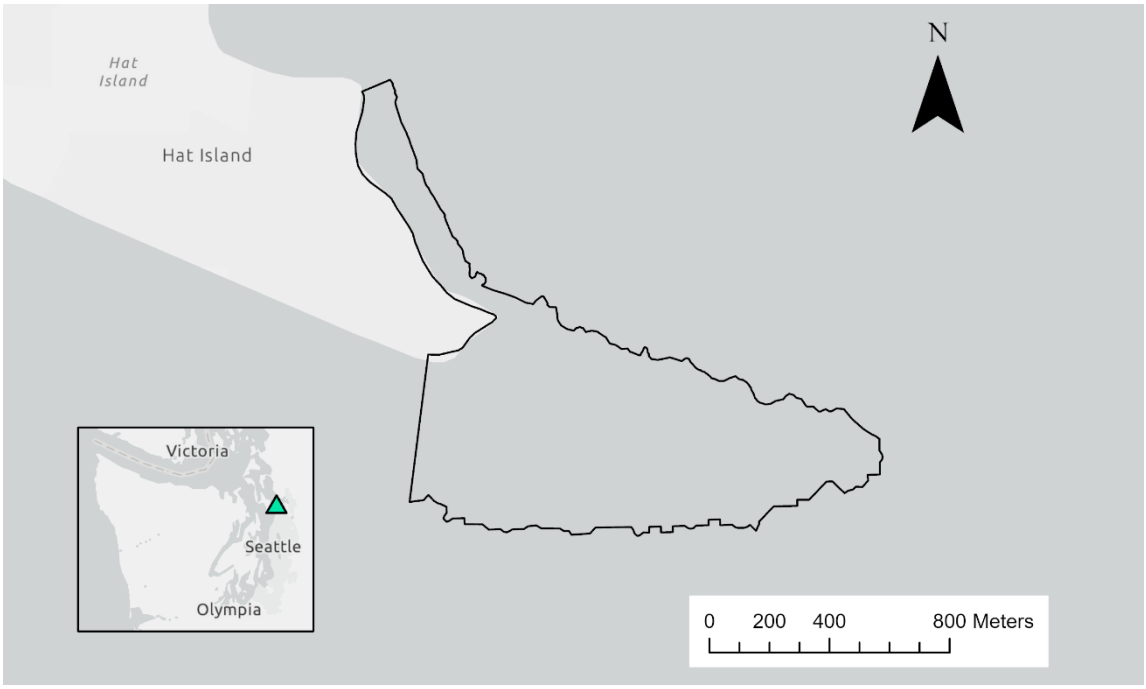


Figure 9. Hat Island Indicator survey extent (black polygon).

Lummi SW: Due to shallow rocks, the polygon follows the shoreward side of the survey lines and extends to the 20 ft bathymetry line. The polygon uses the guidelines provided by NW Straits as the east and west boundaries. The 2016 survey will be excluded because volunteers are uncertain of the full survey extent and are not confident it can be accurately compared to subsequent years.

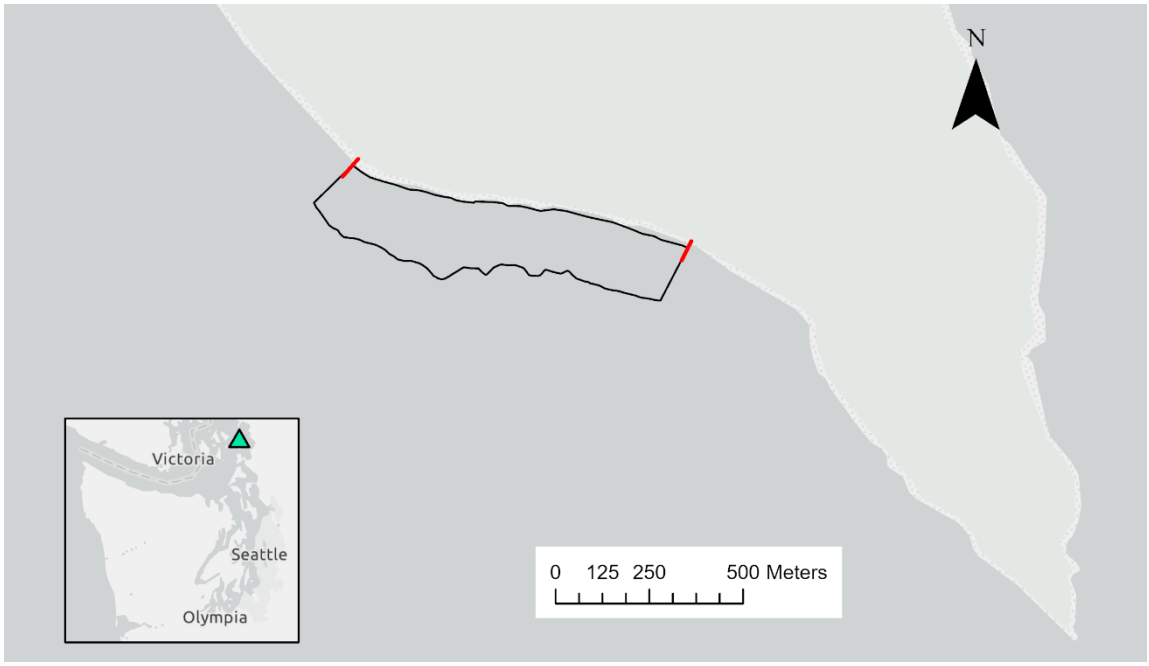


Figure 10. Lummi SW Indicator survey extent (black polygon). Red lines represent shoreline segment (minimum survey areas) created by NW Straits and Whatcom County MRC.

Meadowdale: The polygon extends from the mean high tide line to the 30 ft bathymetry line. The north end of the polygon is at the south end of Meadowdale Beach Park and the polygon extends south along the shoreline all the way to the north boundary of the Edmonds North polygon.

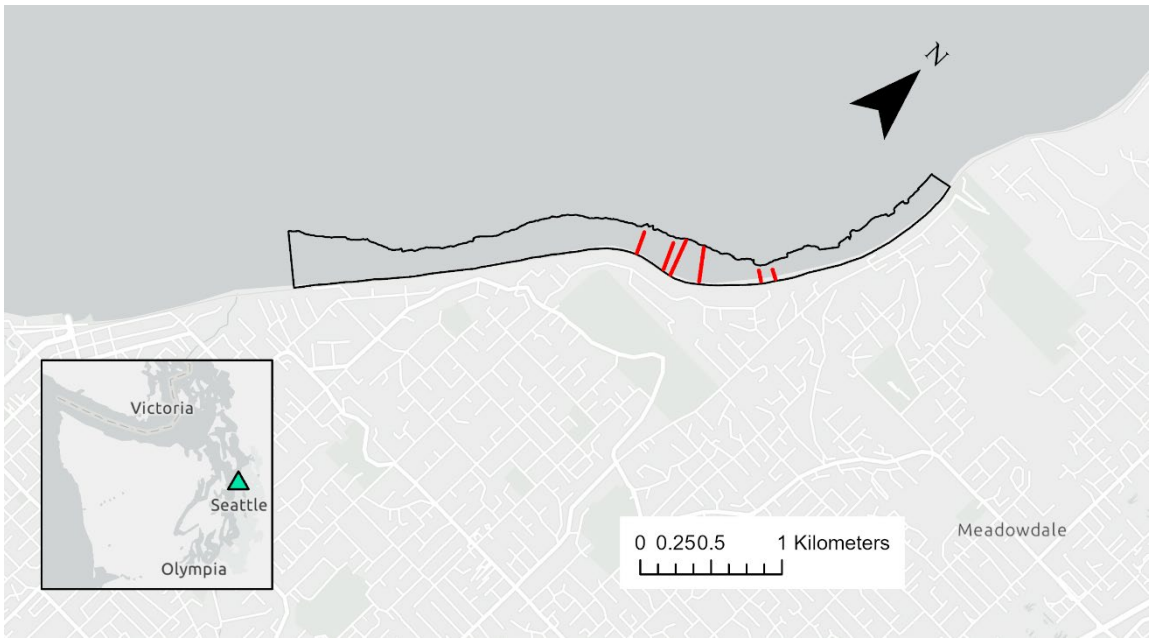


Figure 11. Meadowdale Indicator survey extent (black polygon). Red lines represent shoreline segments (minimum survey areas) created by NW Straits and Snohomish County MRC.

Mukilteo: The polygon extends from the mean high tide line to the 30 ft bathymetry line and runs north-south from the Mukilteo boat launch in the north end to the first house on the beach in the south.

Figure 12. Mukilteo Indicator survey extent (black polygon).

North Beach Main: The polygon extends along the shoreline from the east guideline to the west guideline of the main bed and from the mean high tide line to the 40 ft bathymetry line. The 2015 survey will be excluded from analysis because it was surveyed at high tide and is not comparable to subsequent surveys.

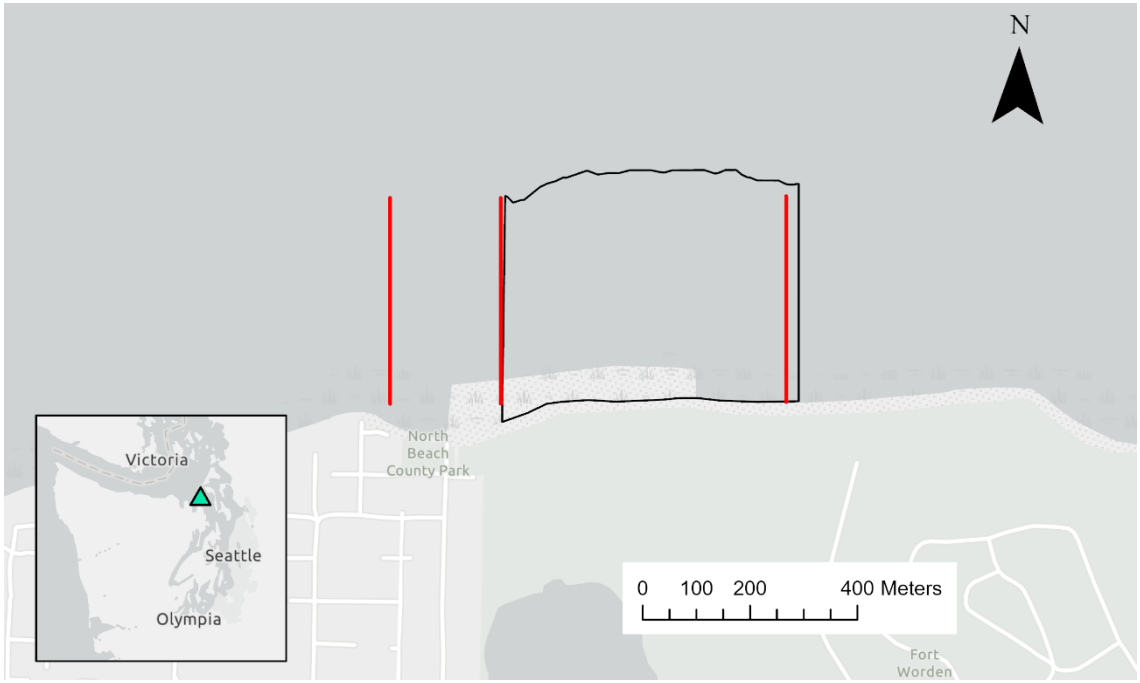


Figure 13. North Beach Main Indicator survey extent (black polygon). Red lines represent shoreline segments (minimum survey areas) created by NW Straits and Jefferson County MRC.

Observatory Point: The polygon runs from the guideline inside Freshwater Bay to the outer rock on Observatory Point and extends from the mean high tide line to offshore of the survey lines. Bathymetry lines were not used to determine the deep side of the polygon because the bathymetry lines do not come into the bay.

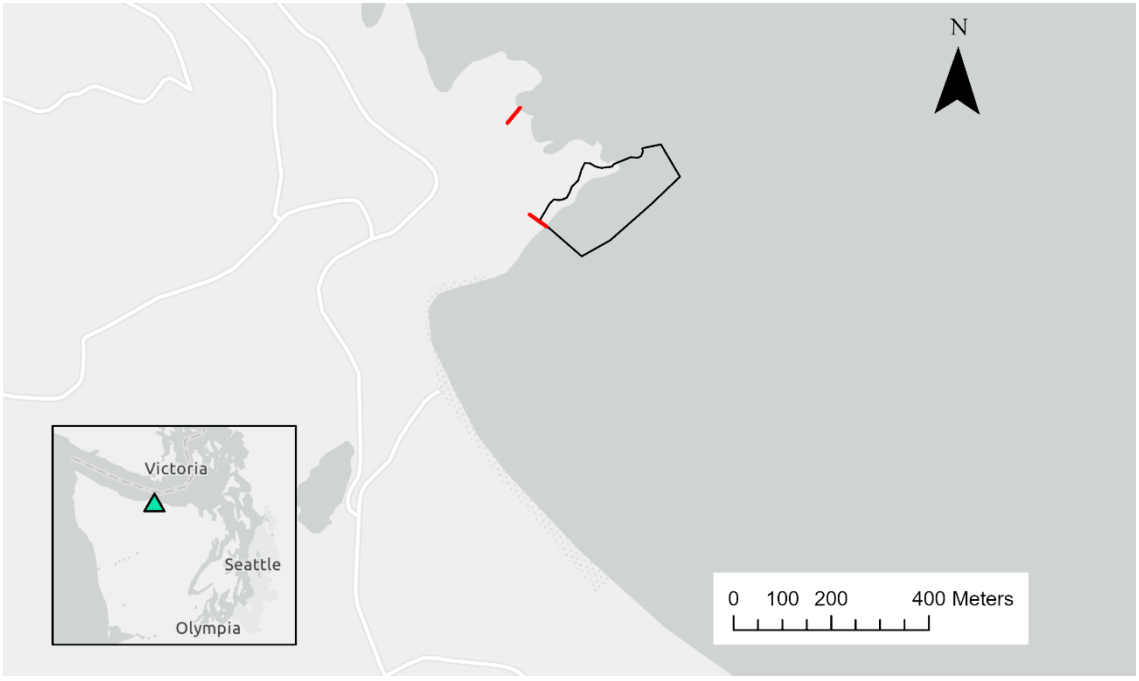


Figure 14. Observatory Point Indicator survey extent (black polygon). Red lines represent shoreline segment (minimum survey areas) created by NW Straits and Clallam County MRC.

Polnell Point: The northwest end of the polygon extends from the mean high tide line to the 30 ft bathymetry line and cuts off the largest survey extents because the north end of the bed cannot be surveyed consistently every year. Near the point, the shoreward edge of the polygon follows the survey lines due to rocks and seals that the surveyors avoid and extends to the 40 ft bathymetry line. The polygon extends to the northeast to a small shoal.

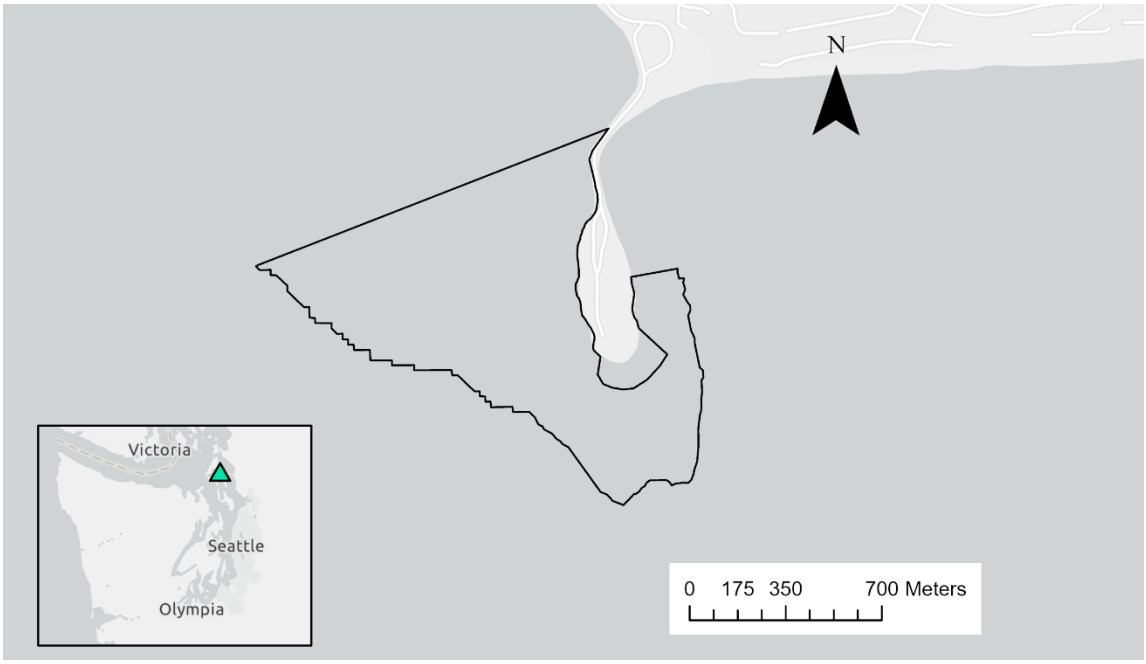


Figure 15. Polnell Point Indicator survey extent (black polygon).

Possession Point: On the northeast side of the site, the polygon starts at the eastern guideline and extends from the mean high tide line to the 40 ft bathymetry line. At the main bed, the shoreward side of the polygon follows the survey lines, and the deep edge extends to the 40 ft bathymetry line. On the west side of the site, the polygon ends at the maximum extent of the 2018 survey. 2018 was the last year before the east and west kelp beds merged and surveyors only mapped the east bed prior to 2019.

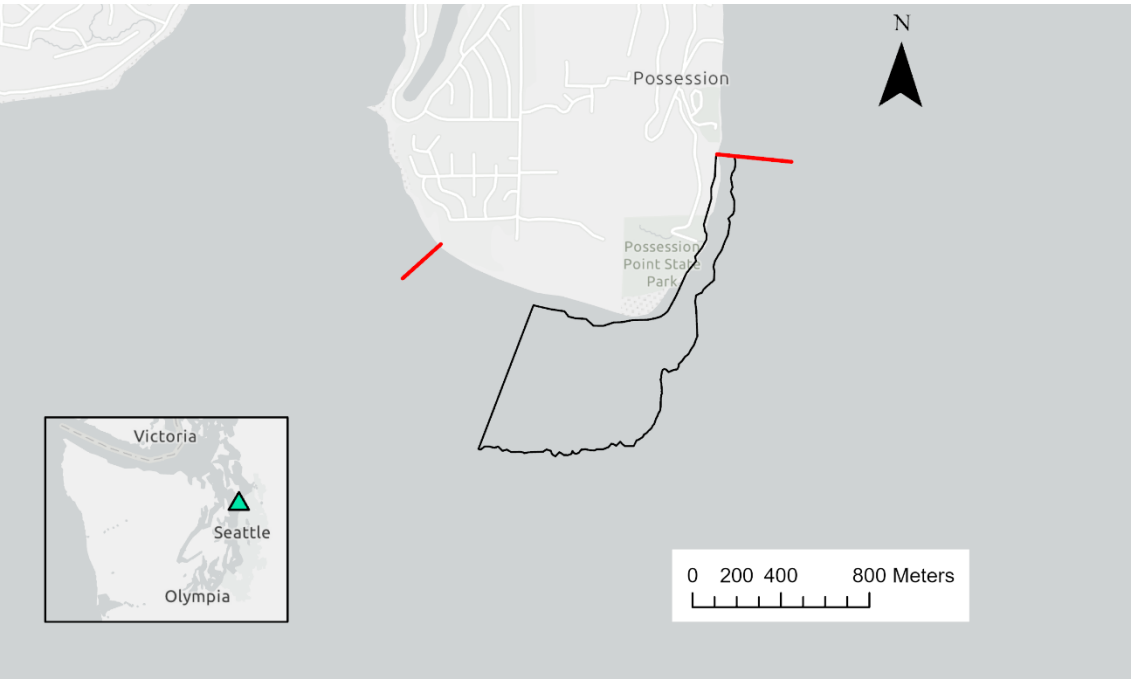


Figure 16. Possession Point Indicator survey extent (black polygon). Red lines represent shoreline segment (minimum survey areas) created by NW Straits and Island County MRC.

Shannon Point East: The polygon runs east from the Shannon Point navigation marker to the guideline at the west end of the ferry parking lot and extends from the mean high tide line to the 30 ft bathymetry line.

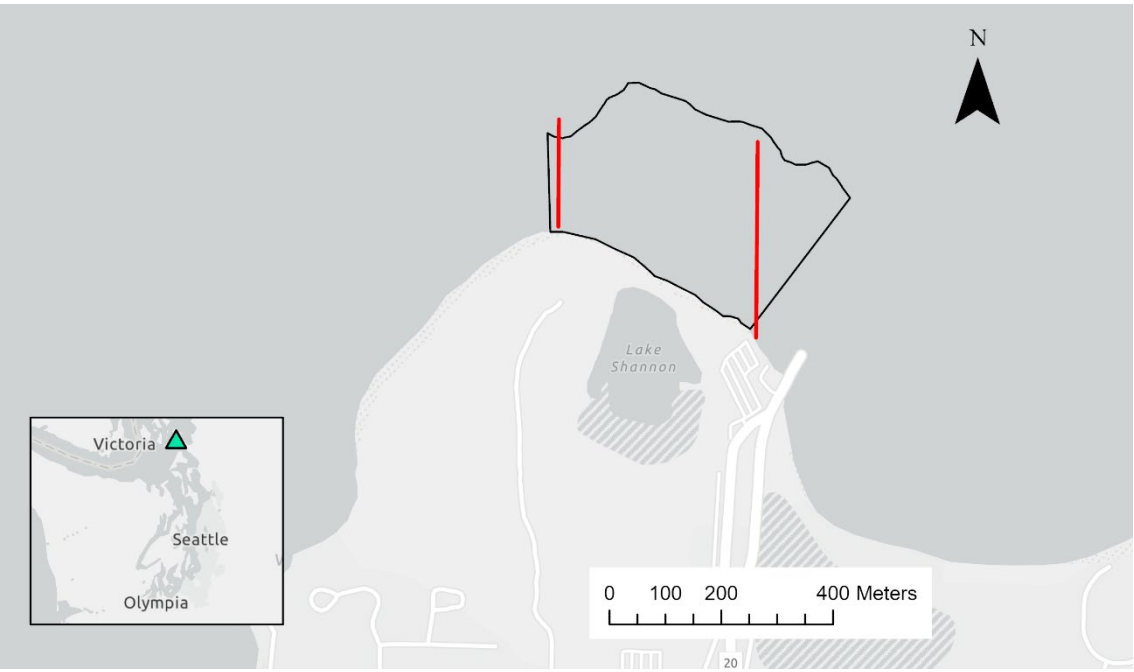


Figure 17. Shannon Point East Indicator survey extent (black polygon). Red lines represent shoreline segment (minimum survey areas) created by NW Straits and Skagit County MRC.

Shannon Point West: The polygon runs west from the Shannon Point navigation marker to the boat launch at Washington Park and extends from the mean high tide line to the 30 ft bathymetry line.

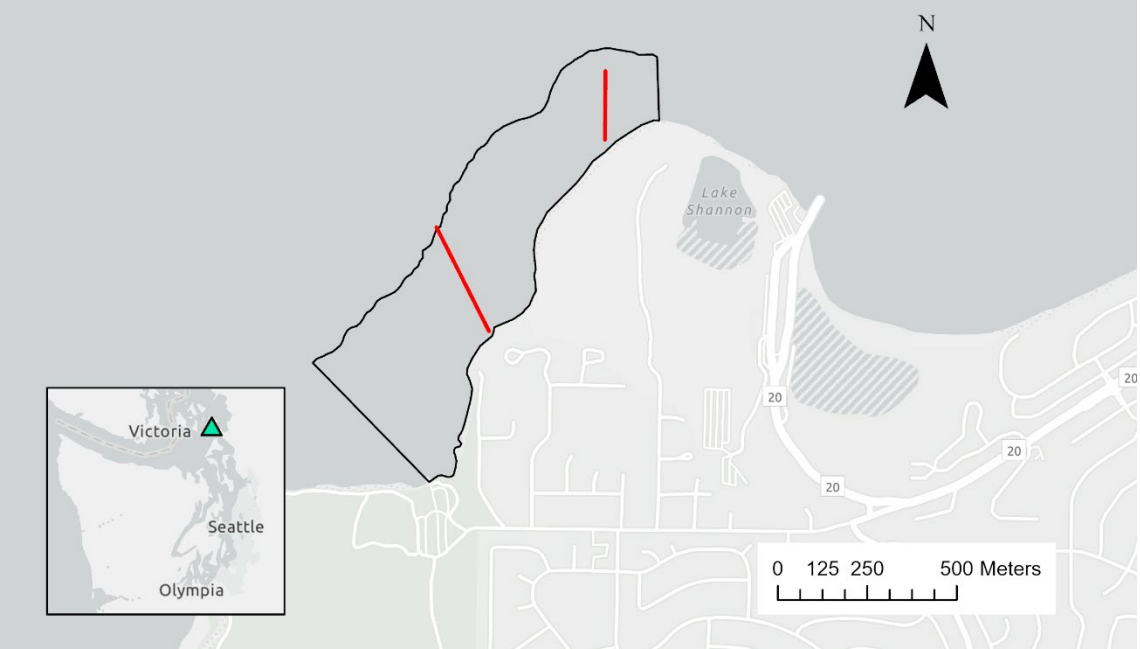


Figure 18. Shannon Point West Indicator survey extent (black polygon). Red lines represent shoreline segments (minimum survey areas) created by NW Straits and Skagit County MRC.

MRC sites that are pending or excluded from Indicator

Aiston Preserve: This is a pending Indicator site. The site has five years of data (2018-2022) and there are plans to survey the site in 2023. It is being considered for inclusion in the Indicator dataset because of the limited data available in North Puget Sound sub-basin and the recent removal of an overwater structure that could benefit kelp growth.

Alden Bank: There is some uncertainty in the bed footprint and in methods used to collect the perimeter. In 2018 and 2019, perimeters were collected by kayak and in 2020 the perimeter collected by tugboat. Aerial imagery is also collected for this site, but the kayak/boat-collected perimeters do not match well to the imagery collected by volunteer pilot, Gregg Ridder. The blue water (site is not along a shoreline) conditions at this large, isolated bed may make it difficult to collect accurate perimeters by kayak or boat. Surveyors do not plan to return to the site.

Ben Ure: This is a pending Indicator site. The site was last surveyed in 2018 and has three years of data (2016-2018). However, it is being considered for inclusion in the Indicator dataset because there is limited kelp data in the Saratoga/Whidbey sub-basin.

Camano Island: This is a pending Indicator site. The site was last surveyed in 2022 and has five years of data (2016-2017, 2020-2022). There are plans to survey the site in 2023. It is being considered for inclusion in the Indicator dataset because there is limited kelp data in the Saratoga/Whidbey sub-basin.

Fawn Island: This site was last surveyed in 2017 and likely won't be surveyed again. It has two years of data (2016-2017), which is insufficient for determining change but may be helpful to support other datasets.

Hastie Lake: This site was surveyed in 2015, and it was decided that the conditions were not good for kayak surveys. Surveyors did not return to the site.

Hoypus Point: This is a pending Indicator site. The site was last surveyed in 2022 and has five years of data (2016-2018, 2022) and there are plans to survey the site in 2023. It is being considered for inclusion in the Indicator dataset because there is limited kelp data in the Saratoga/Whidbey sub-basin.

Libbey Beach: This site was surveyed in 2015 and it was decided that the conditions were not good for kayak surveys. Surveyors did not return to the site.

North Beach West: This site was surveyed twice (2016 and 2019) and the area surveyed differs between years. This area was mainly surveyed in response to a proposal to move an outflow pipe. It would be best to use the North Beach Main site for long-term data.

Pole Pass: This site was last surveyed in 2017 and likely won't be surveyed again. There are three years of data (2015-2017), which is insufficient for determining change but may be helpful to support other datasets.

Point Whitehorn: This is a pending Vital Sign site. It has an inconsistent bed footprint, some years the bed mapped is larger and other years it is much smaller. This could be in part due to the challenging conditions (swell, wind) the surveyors encounter. There is some uncertainty in what would be a consistently mapped area (smaller to be very confident the area has been mapped every year or slightly larger to capture the variability seen on the deeper edge of the bed).

Reef Island: This site was last surveyed in 2017 and likely won't be surveyed again. It has two years of data (2016-2017), which is insufficient for determining change but may be helpful to support other datasets.

Appendix 5: MRC StoryMap Outline

The following outline was developed by DNR and NW Straits to guide the MRC kelp StoryMap development.

Overall Landing Page

Goal: Single updateable page including interactive map of kelp bed perimeters with the ability to dig into data

- Link to Sound IQ Data Viewer or webmap
    - Map has all collected perimeters for all the sites
    - Develop a pop up for each MRC kayak site to show summary information and graphs
        - This could be a bar graph or another graph that is easy to interpret without much explanation.

Introduction/Project overview

Goal: introduce the project and the MRCs

- Overview of project, purpose of project
    - Take from other NW Straits StoryMap intros
- What Marine Resources Committees are
    - MRC purpose
- Brief description of methods and link to protocol (with a challenges section)
- Highlights of what we've learned (pull out little stories – losses in Snohomish, increase at Ebey's compared to aerial data, seasonal differences, animals that use the kelp bed, synthesis into Vital Sign)

County pages/tabs

Goal: Tell a story, what is unique about this county/site, make it a "family album"

- Describe each site
    - Site description with map on the side (imagery with site extent/shoreline segments)
    - Local bed conditions (calm, high energy, etc.)
    - List of species seen at the site?
- Heavy on visuals
    - For each site:
        - use aerial imagery if available

        - 3-5 photos of volunteers (counties with multiple sites, one photo per site)
        - 1-2 photos of the kelp bed
- Incorporate personality of each county
    - Include quotes or vignettes from volunteers about sites (come up with questions to ask them) (or aha paragraphs from each site - notes/observations from volunteers)
        - How would you describe your site?/Describe your site in 5 words
        - Why did you decide to join this project?
        - Why is kelp important to you?
        - What changes in kelp (if any) have you observed at your site?
        - What do you find most rewarding about monitoring your local kelp bed?
    - Include videos from surveys if available
    - List extra data the county collects
    - Link to county MRC pages

Appendix 6: Interactive Map One-Page Site Summaries

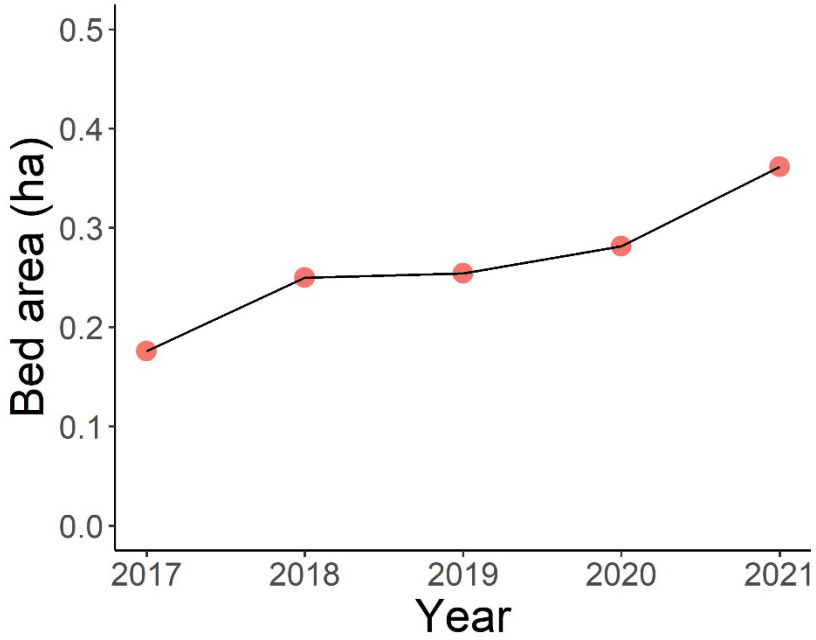
This appendix contains the one-page summaries (sorted alphabetically) for each MRC site included in the Floating Kelp Bed Area Indicator. The summaries are integrated into interactive map for the indicator as pop-ups.

Location: Biz Point (BZPT)

Sub-basin: Eastern Strait

More information:
[Skagit County MRC]
[NW Straits Commission]

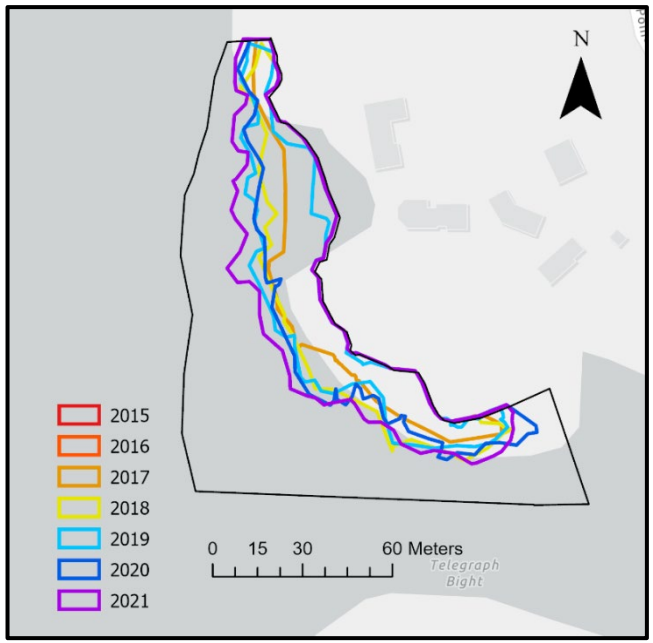
Kelp Forests WA



Recent (5 yr) bed trend: **No trend**

Entire data record: **No trend**

Skagit County Marine Resources Committee (MRC) volunteers have monitored Biz Point since 2017. Bed area increased slightly but has been stable overall (no significant trend). Volunteers noted that kelp has seemed denser and has started to grow further south. Trend results at this site span a limited number of years, continuing to collect data will enrich our understanding.

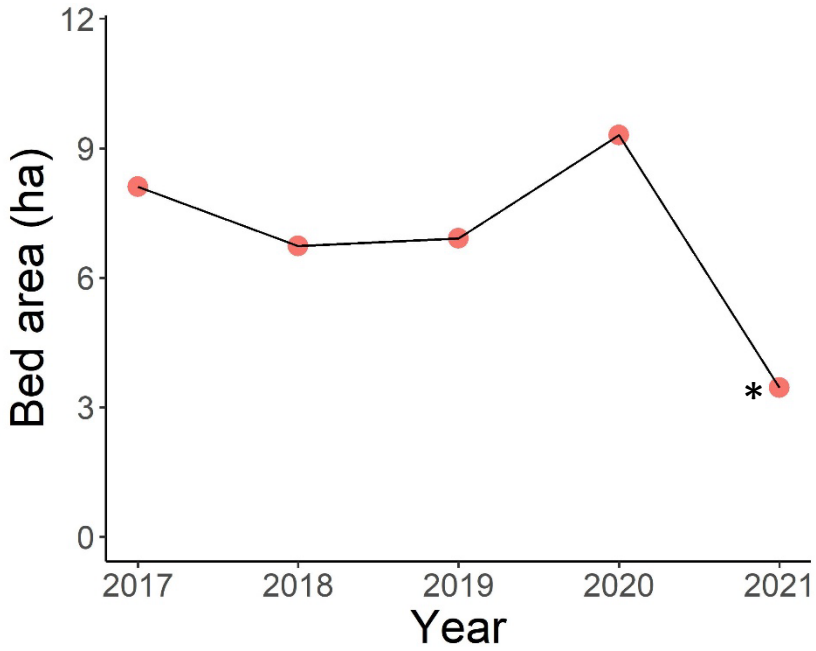


To explore the spatial data visit [Sound IQ]

Location: Cherry Point (CHPT)

Sub-basin: North Puget Sound

More information:
[Whatcom County MRC]
[NW Straits Commission]

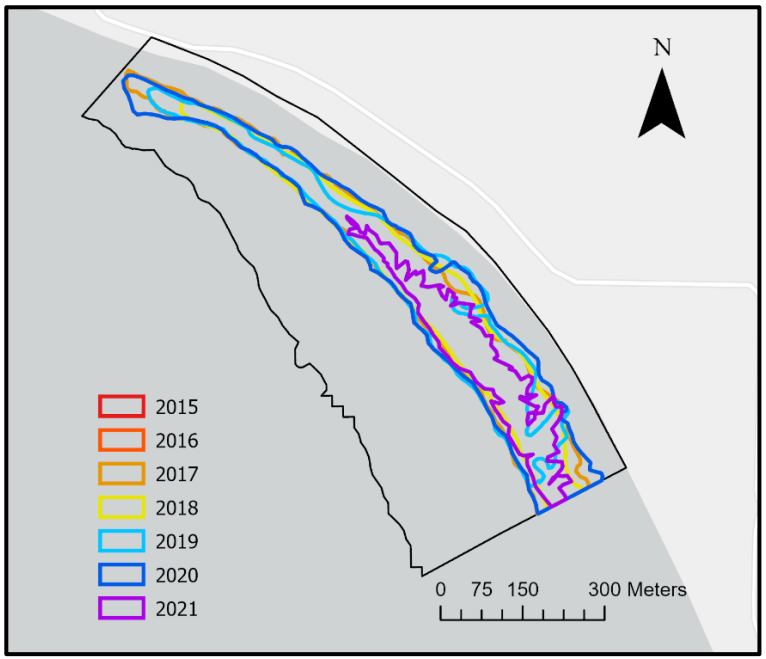


Recent (5 yr) bed trend: **No trend**

Entire data record: **No trend**

Whatcom County Marine Resources Committee (MRC) volunteers have monitored Cherry Point since 2017. Bed area has been highly variable and stable overall (no significant trend). Trend results at this site span a limited number of years, continuing to collect data will enrich our understanding.

*The 2021 survey did not capture the entire floating kelp bed, volunteers noted that data was lost due to a GPS malfunction.

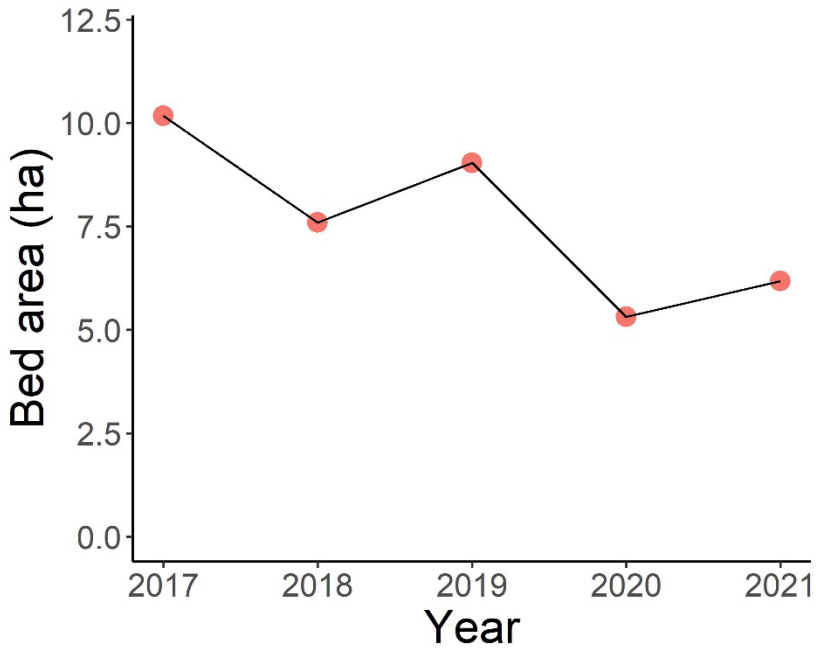


To explore the spatial data visit [Sound IQ]

Location: Clallam Bay (CLLB)

Sub-basin: Western Strait

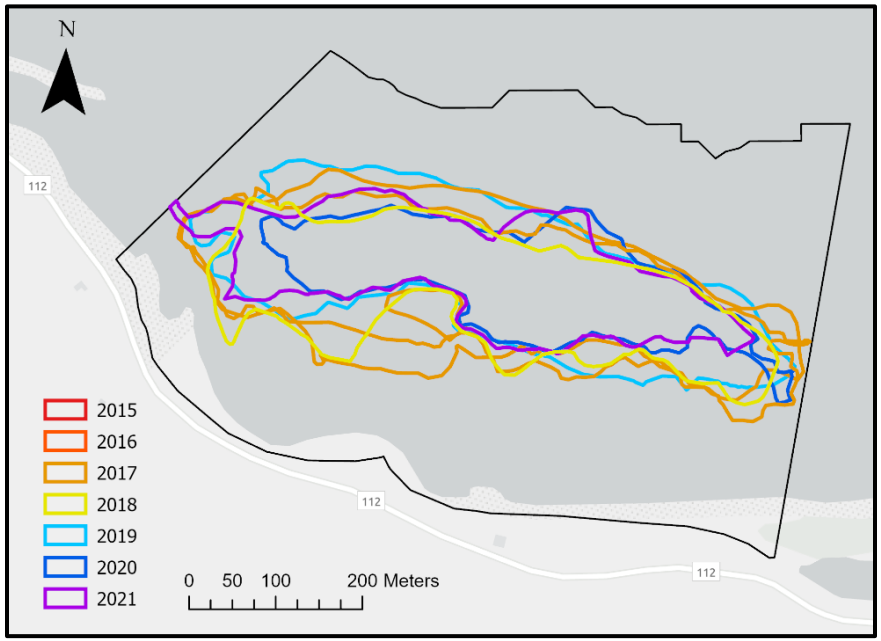
More information:
[Clallam County MRC]
[NW Straits Commission]



Recent (5 yr) bed trend: **No trend**

Entire data record: **No trend**

Clallam County Marine Resources Committee (MRC) volunteers have monitored Clallam Bay since 2017. Bed area has been highly variable but stable overall (no significant trend). Volunteers noted that year-to-year variation in kelp density and wave action can influence bed area. Trend results at this site span a limited number of years, continuing to collect data will enrich our understanding.



To explore the spatial data visit [Sound IQ]

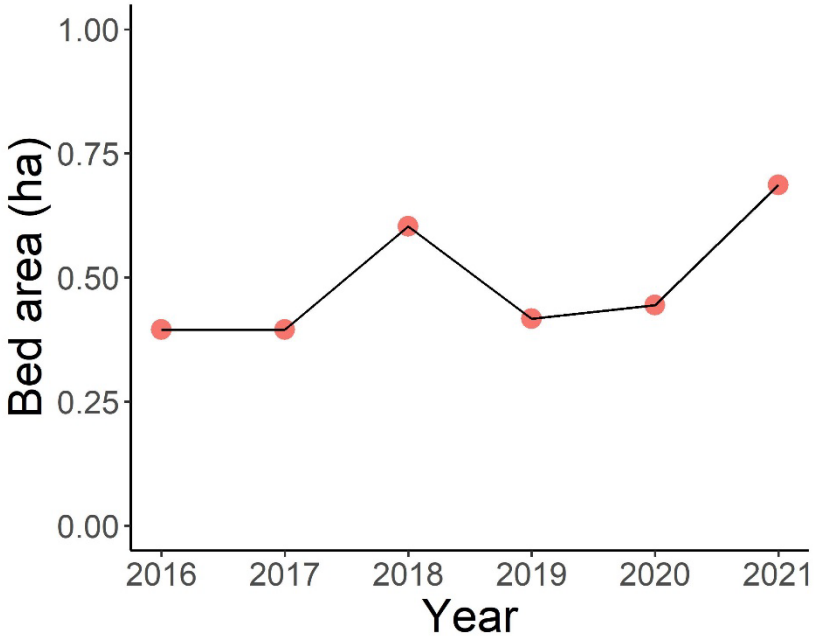

Photo credit: Alan Clark

Location: Coffin Rocks (COFF)

Sub-basin: Eastern Strait

More information:
[Skagit County MRC]
[NW Straits Commission]

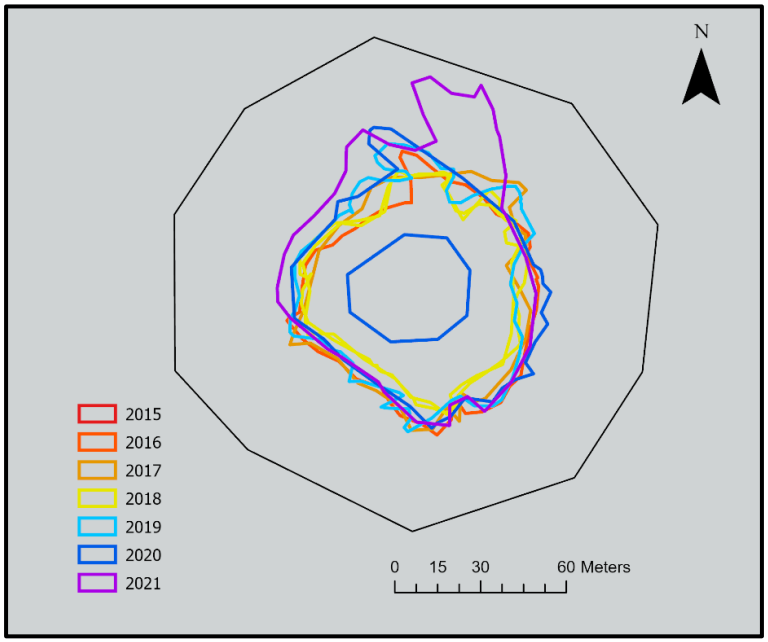
Kelp Forests WA



Recent (5 yr) bed trend: **No trend**

Entire data record: **No trend**

Skagit County Marine Resources Committee (MRC) volunteers have monitored Coffin Rocks since 2016. Bed area increased slightly but remained stable overall (no significant trend). Volunteers noted that kelp density is variable year to year while the bed perimeter changes little. Trend results at this site span a limited number of years, continuing to collect data will enrich our understanding.

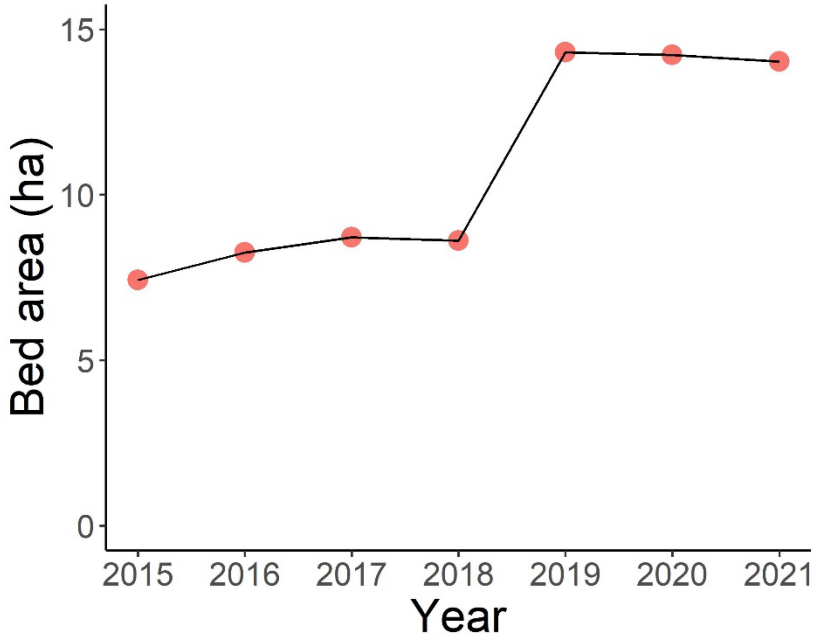


To explore the spatial data visit [Sound IQ]

Location: Ebey's Landing (EBL)

Sub-basin: Eastern Strait

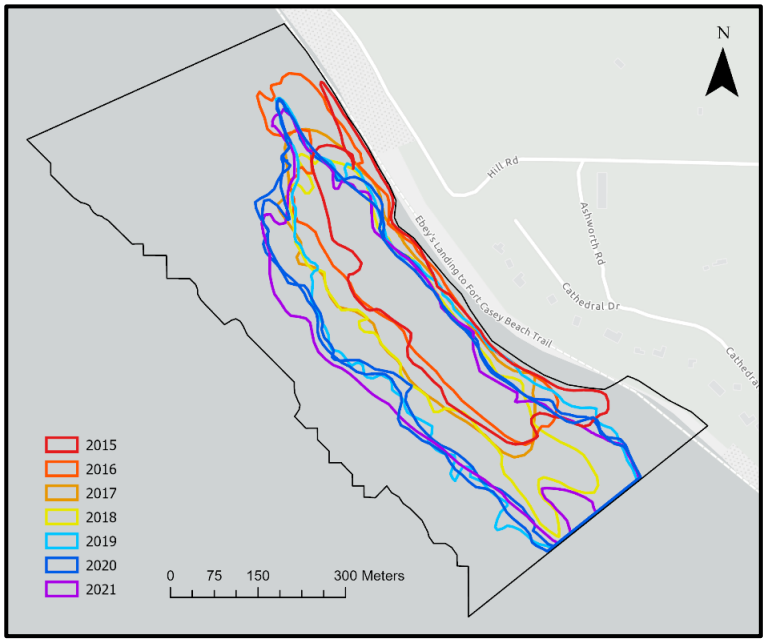
More information:
[Island County MRC]
[NW Straits Commission]



Recent (5 yr) bed trend: **Increasing**

Entire data record: **Increasing**

Island County Marine Resources Committee (MRC) volunteers have monitored Ebey's Landing since 2015. In 2019, bed area increased. Volunteers observed the bed expand into deeper water and extend further south, merging with a kelp bed to the southeast. Trend results at this site span a limited number of years, continuing to collect data will enrich our understanding.



To explore the spatial data visit [Sound IQ]

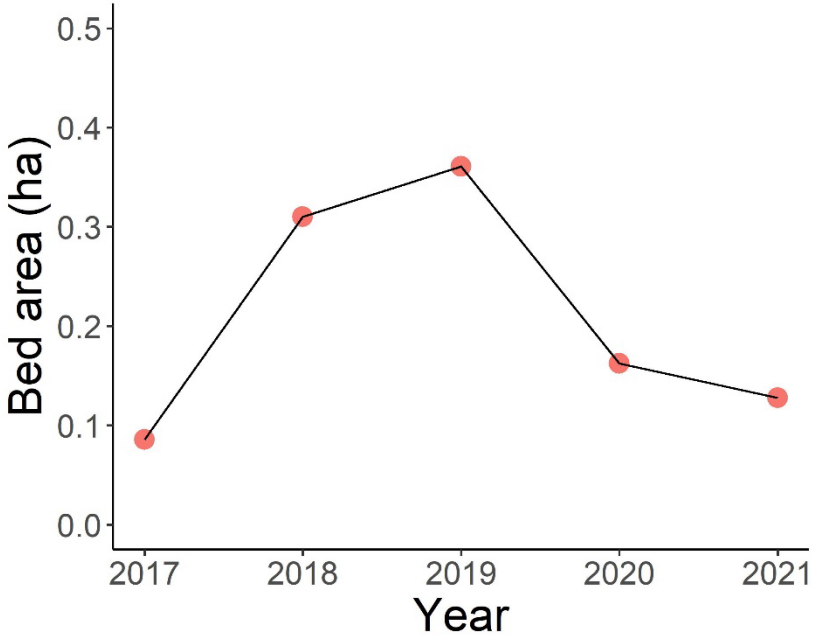

Photo credit: Rich Yukubousky

Location: Edmonds – Dive Park (ED-DP)

Sub-basin: Central Puget Sound

More information:
[Snohomish County MRC]
[NW Straits Commission]

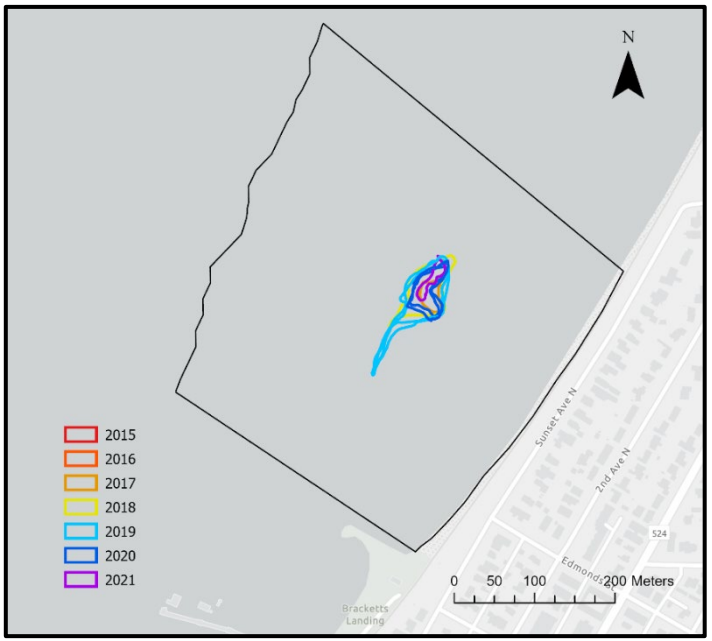
Kelp Forests WA



Recent (5 yr) bed trend: **No trend**

Entire data record: **No trend**

Snohomish County Marine Resources Committee (MRC) volunteers have monitored Edmonds – Dive Park since 2017. This site is located within the Edmonds Dive Park just north of the Edmonds ferry terminal. Bed area has been highly variable and stable overall (no significant trend). Trend results at this site span a limited number of years, continuing to collect data will enrich our understanding.



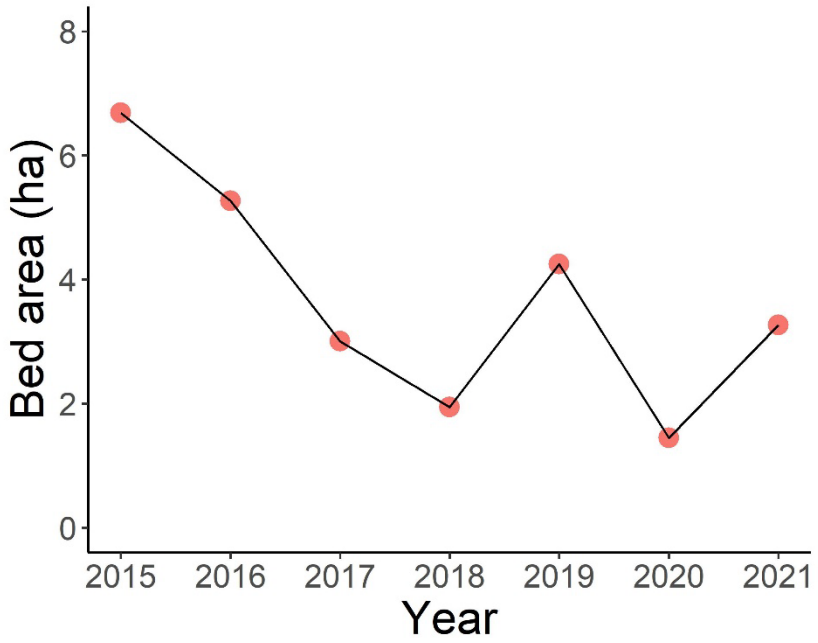
To explore the spatial data visit [Sound IQ]

Location: Edmonds – North (ED-N)

Sub-basin: Central Puget Sound

More information:
[Snohomish County MRC]
[NW Straits Commission]

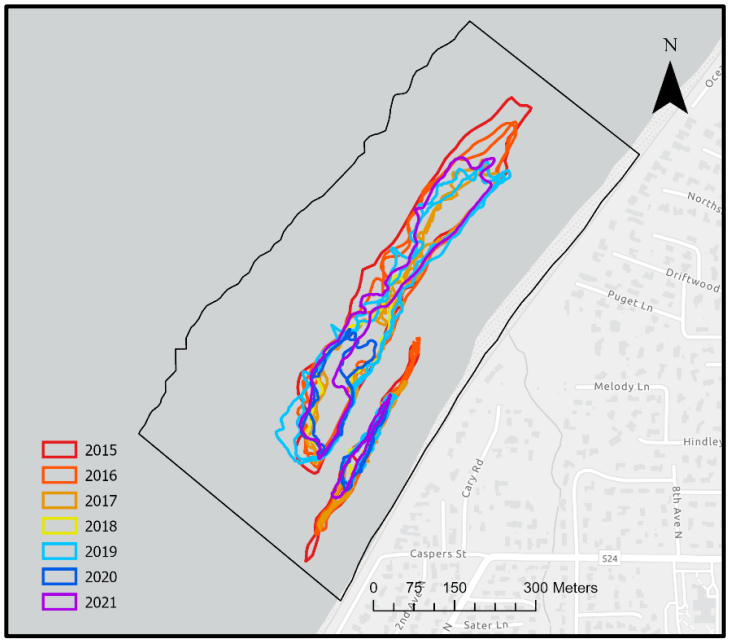
Kelp Forests WA



Recent (5 yr) bed trend: **No trend**

Entire data record: **No trend**

Snohomish County Marine Resources Committee (MRC) volunteers have monitored Edmonds – North since 2015. Bed area has been highly variable and stable overall (no significant trend). Volunteers noted both shallow and deep kelp beds have contracted on the north and south ends in recent years. Trend results at this site span a limited number of years, continuing to collect data will enrich our understanding.



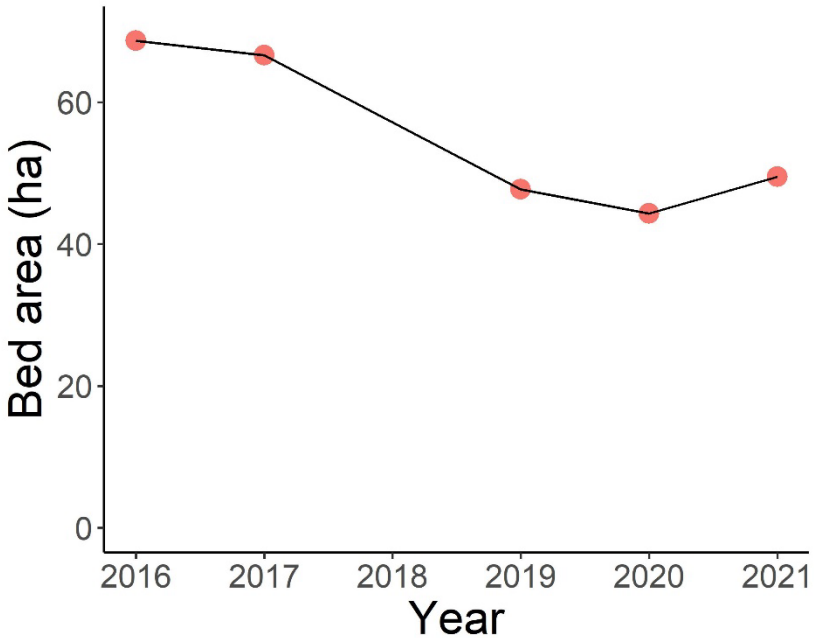
To explore the spatial data visit [Sound IQ]

Photo credit: Elisa Dawson

Location: Freshwater Bay (FWB)

Sub-basin: Eastern Strait

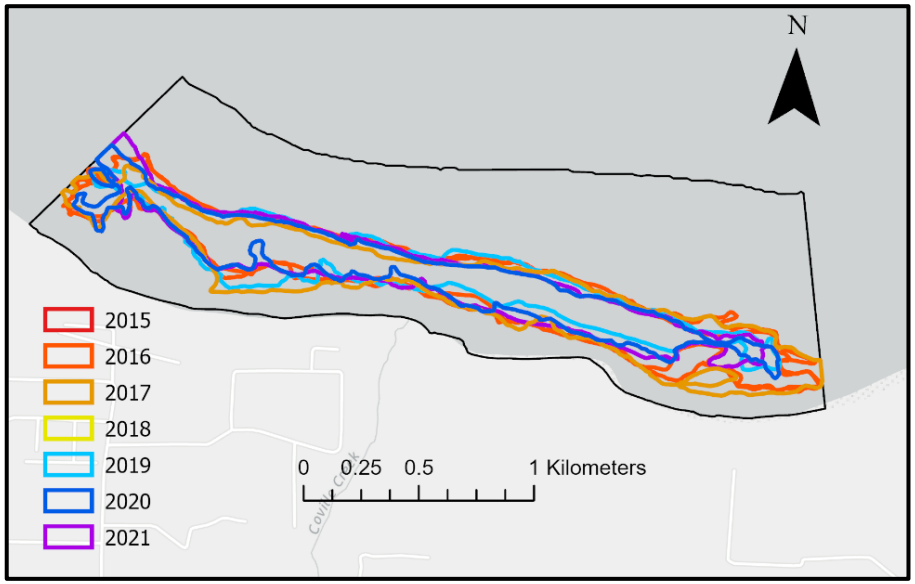
More information:
[Clallam County MRC]
[NW Straits Commission]



Recent (5 yr) bed trend: **Decreasing**

Entire data record: **Decreasing**

Clallam County Marine Resources Committee (MRC) volunteers have monitored Freshwater Bay since 2016. Bed area contracted slightly on the eastern side. This location is adjacent to the mouth of the Elwha River, changes may be related to dam removal on the river, which occurred in 2011. Trend results at this site span a limited number of years, continuing to collect data will enrich our understanding.



To explore the spatial data visit [Sound IQ]

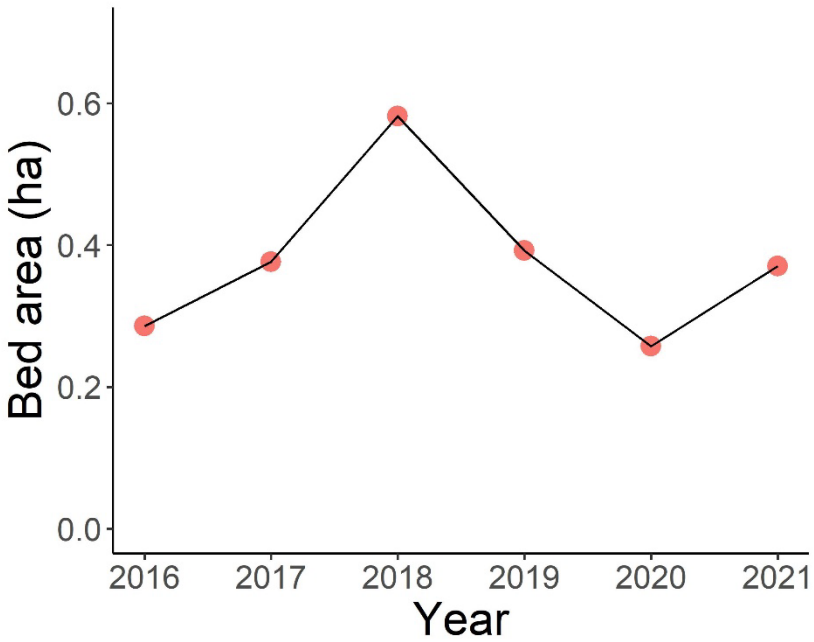

Photo credit: Jeff Ward

Location: Observatory Point (FWBO)

Sub-basin: Eastern Strait

More information:
[Clallam County MRC]
[NW Straits Commission]

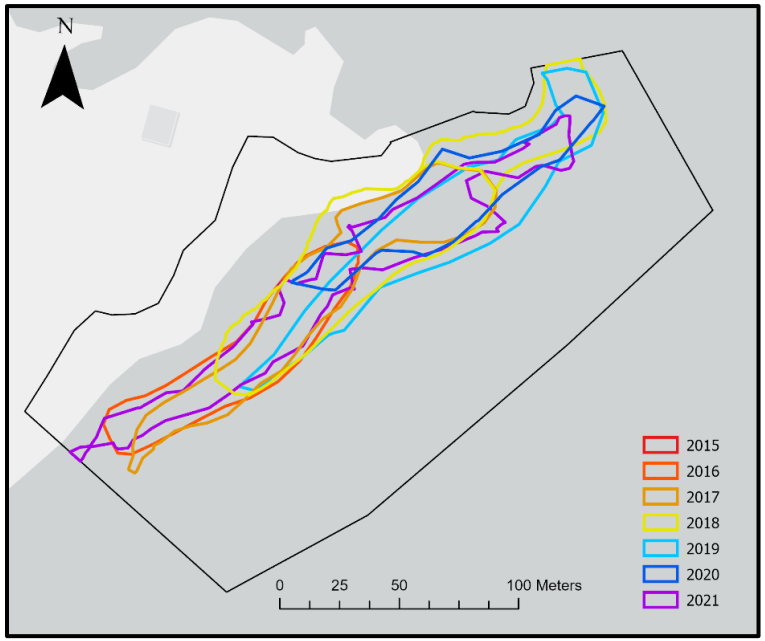
Kelp Forests WA



Recent (5 yr) bed trend: **No trend**

Entire data record: **No trend**

Clallam County Marine Resources Committee (MRC) volunteers have monitored Observatory Point since 2016. Bed area has varied slightly but remained stable overall (no significant trend). Volunteers have observed that the location of the bed varies year to year. Trend results at this site span a limited number of years, continuing to collect data will enrich our understanding.



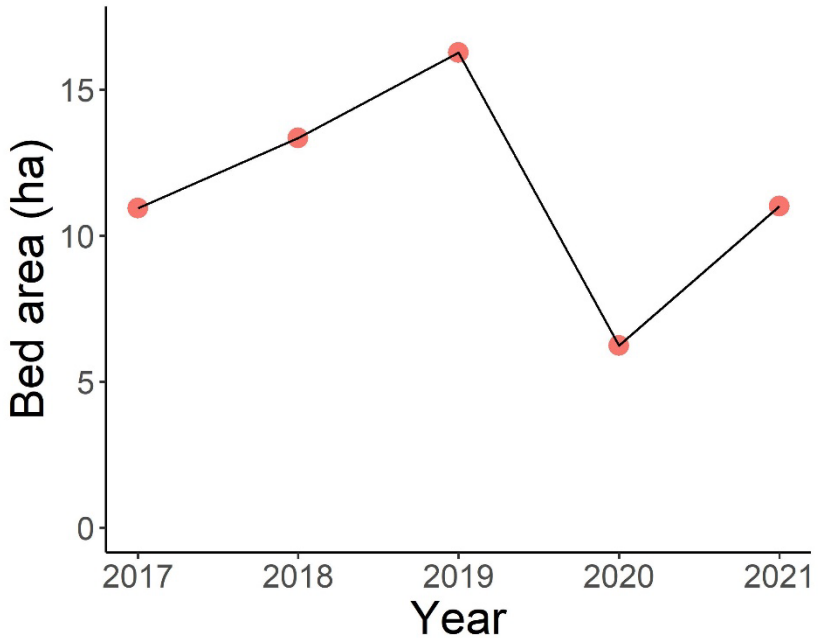
To explore the spatial data visit [Sound IQ]

Location: Hat Island (HAT)

Sub-basin: Saratoga/Whidbey Basin

More information:
[Snohomish County MRC]
[NW Straits Commission]

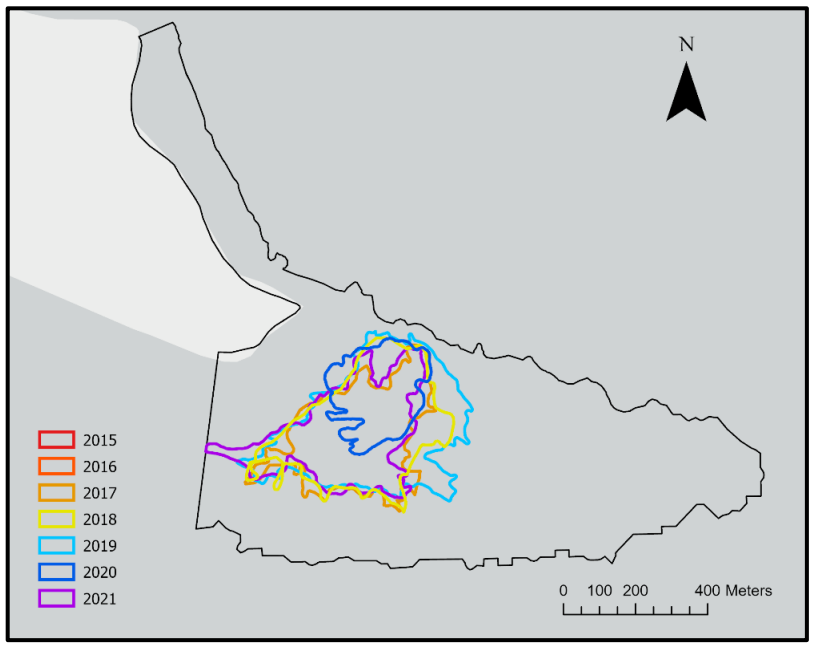
Kelp Forests WA



Recent (5 yr) bed trend: **No trend**

Entire data record: **No trend**

Snohomish County Marine Resources Committee (MRC) volunteers have monitored Hat Island since 2017. This site is located near the mouth of the Snohomish River and is mapped by motor boat. Bed area has been variable but stable overall (no significant trend). Trend results at this site span a limited number of years, continuing to collect data will enrich our understanding.



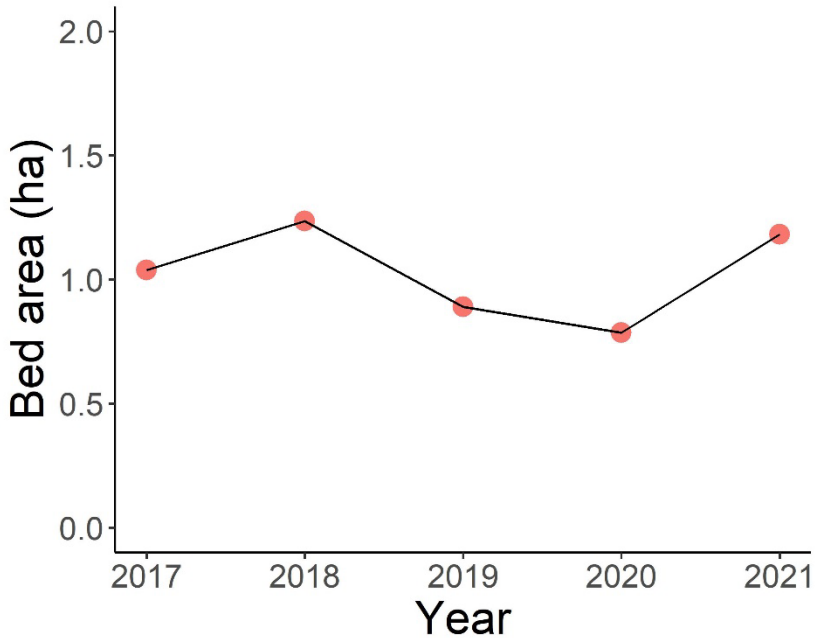
To explore the spatial data visit [Sound IQ]

Photo credit: Elisa Dawson

Location: Lummi Island (LMMI)

Sub-basin: North Puget Sound

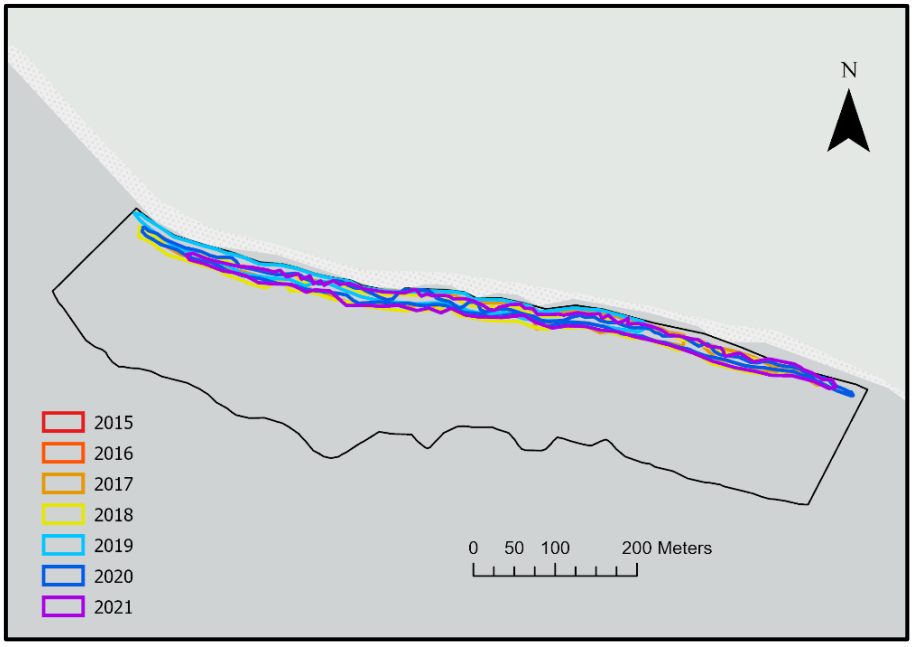
More information:
[Whatcom County MRC]
[NW Straits Commission]



Recent (5 yr) bed trend: **No trend**

Entire data record: **No trend**

Whatcom County Marine Resources Committee (MRC) volunteers have monitored Lummi Island since 2017. Bed area has varied slightly but remained stable overall (no significant trend). Volunteers noted that the shoreward edge is rocky and can be tricky to map. Trend results at this site span a limited number of years, continuing to collect data will enrich our understanding.



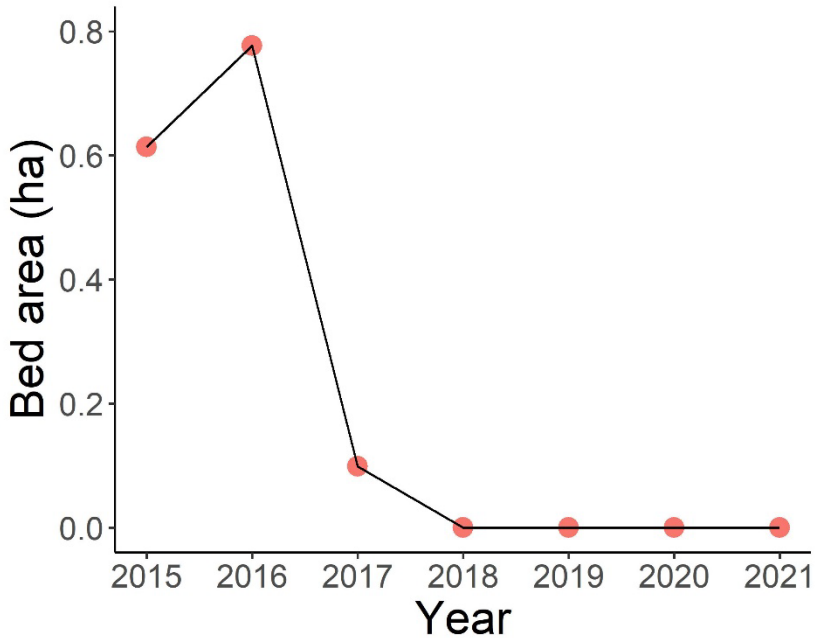
To explore the spatial data visit [Sound IQ]


Photo credit: Eleanor Hines

Location: Meadowdale (MDL)

Sub-basin: Central Puget Sound

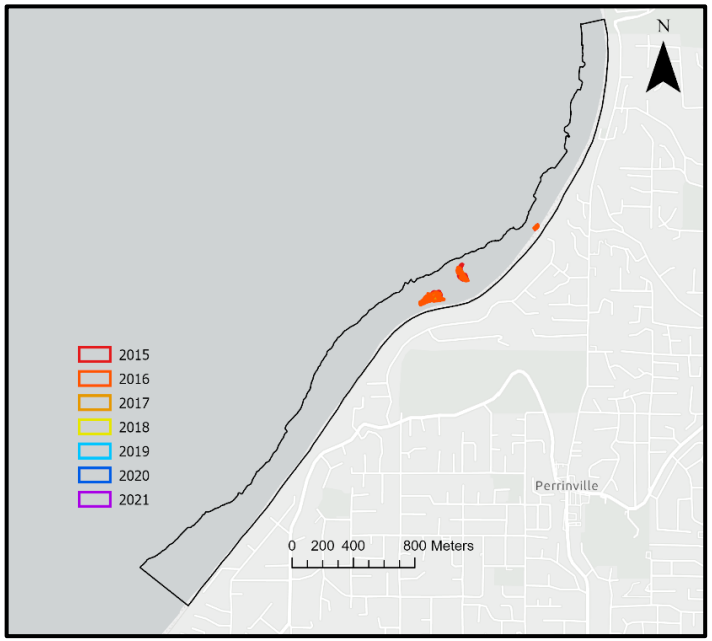
More information:
[Snohomish County MRC]
[NW Straits Commission]



Recent (5 yr) bed trend: **Total loss**

Entire data record: **Total loss**

Snohomish County Marine Resources Committee (MRC) volunteers have monitored Meadowdale since 2015. Bed area declined from 2016 to 2017 and in 2018, only scattered kelp plants remained. By 2020, kelp was completely lost at the site and has not recovered. Volunteers still survey the site for signs of recovery. Continued monitoring of this site is valuable to understanding kelp dynamics.



To explore the spatial data visit [Sound IQ]

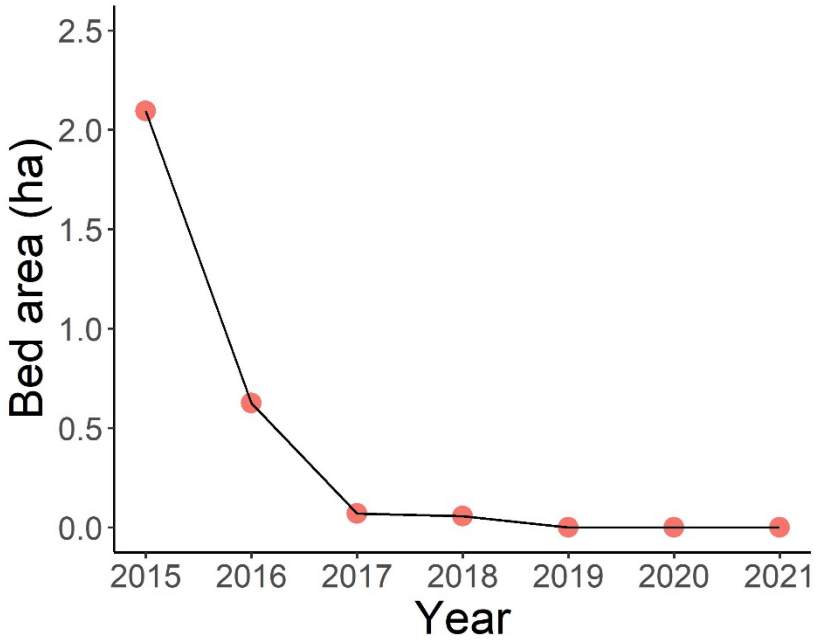
Photo credit: Elisa Dawson

Location: Mukilteo (MKTO)

Sub-basin: Saratoga/Whidbey Basin

More information:
[Snohomish County MRC]
[NW Straits Commission]

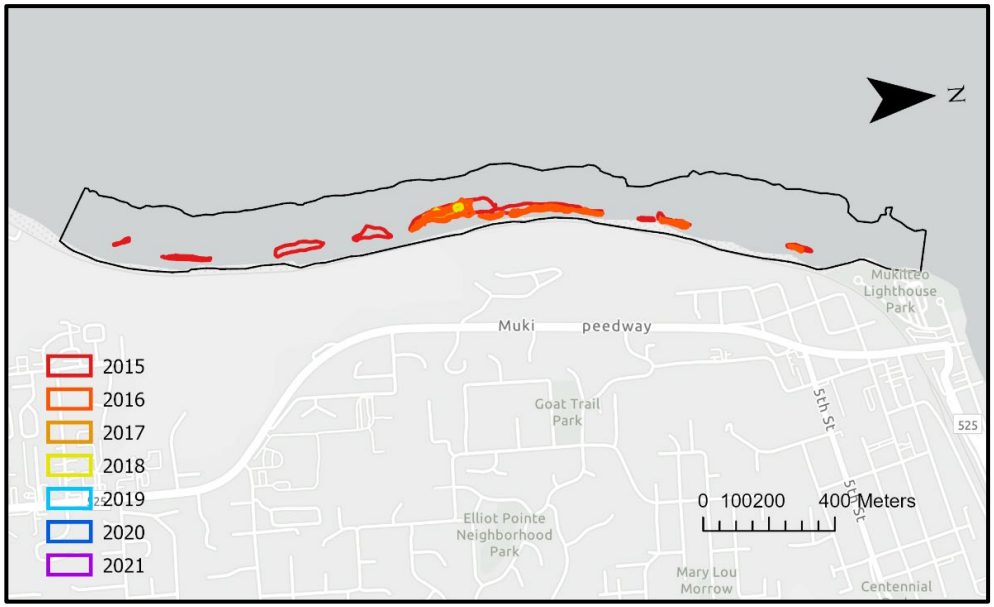
Kelp Forests WA



Recent (5 yr) bed trend: **Total loss**

Entire data record: **Total loss**

Snohomish County Marine Resources Committee (MRC) volunteers have monitored Mukilteo since 2015. Bed area declined from 2015 to 2018 and in 2019, only scattered kelp plants remained. By 2020, kelp was completely lost at the site and has not recovered. Volunteers still survey the site for signs of recovery. Continued monitoring of this site is valuable to understanding kelp dynamics.



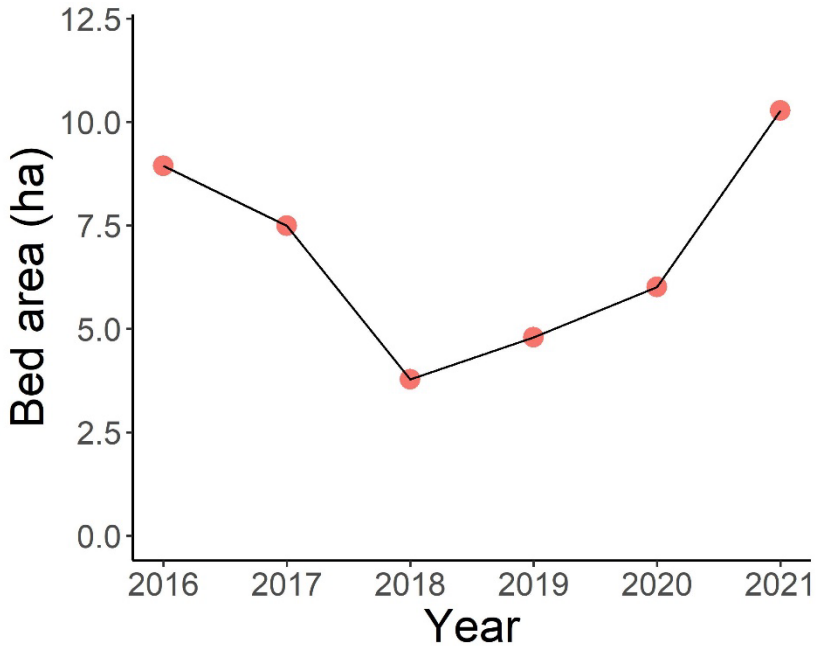
To explore the spatial data visit [Sound IQ]


Photo credit: Elisa Dawson

Location: North Beach – Main (NB-M)

Sub-basin: Eastern Strait

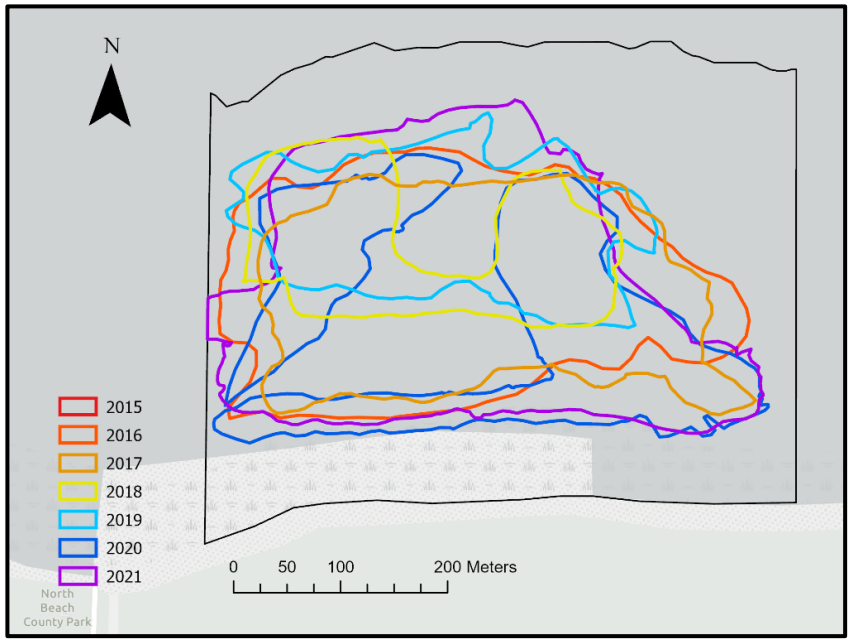
More information:
[Jefferson County MRC]
[NW Straits Commission]



Recent (5 yr) bed trend: **No trend**

Entire data record: **No trend**

Jefferson County Marine Resources Committee (MRC) volunteers have monitored North Beach – Main since 2016. Bed area has been highly variable but remained stable overall (no significant trend). Volunteers have reported that year-to-year variation in kelp density can influence the bed area and location. Trend results at this site span a limited number of years, continuing to collect data will enrich our understanding.



To explore the spatial data visit [Sound IQ]

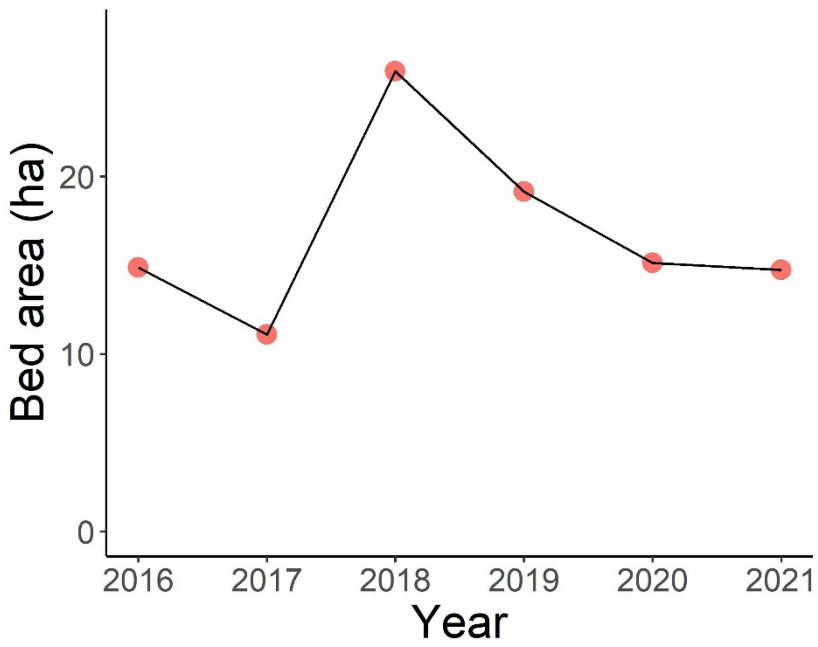

Photo credit: Solenne Walker

Location: Polnell Point (POLN)

Sub-basin: Saratoga/Whidbey Basin

More information:
[Island County MRC]
[NW Straits Commission]

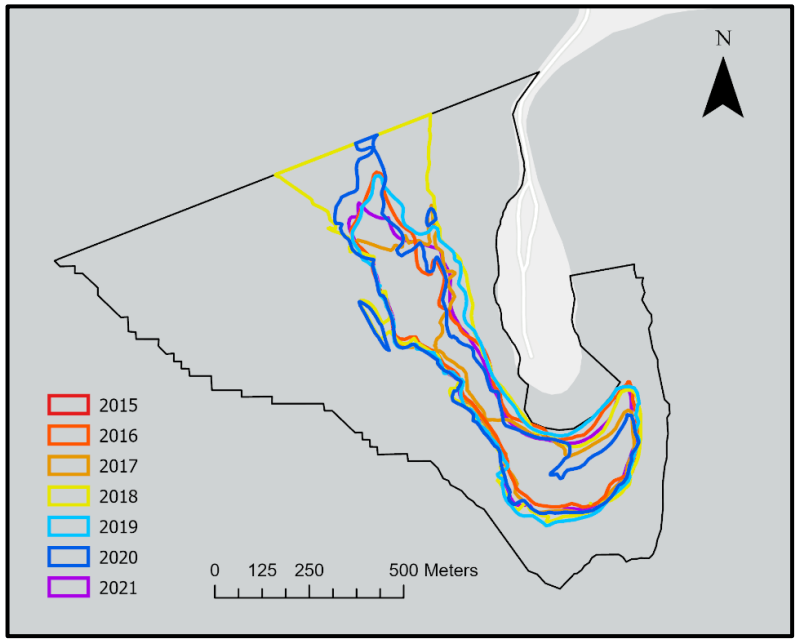
Kelp Forests WA



Recent (5 yr) bed trend: **No trend**

Entire data record: **No trend**

Island County Marine Resources Committee (MRC) volunteers have monitored Polnell Point since 2016. Bed area has been variable but stable overall (no significant trend). Volunteers noted the greatest year-to-year variation occurred in the northwestern portion, where plants were dense in some years and sparse in other years. Trend results at this site span a limited number of years, continuing to collect data will enrich our understanding.



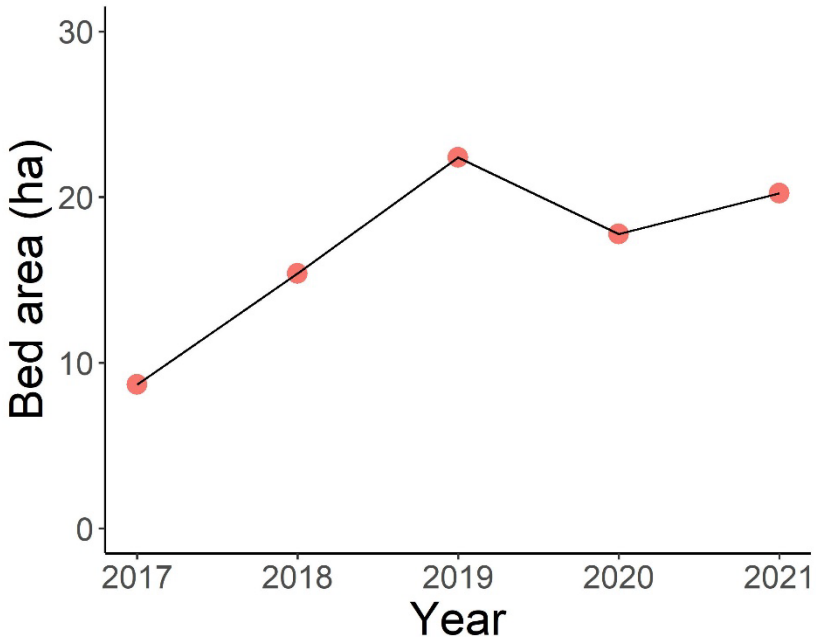
To explore the spatial data visit [Sound IQ]


Photo credit: Vernon Brisley

Location: Possession Point (POSS)

Sub-basin: Admiralty Inlet

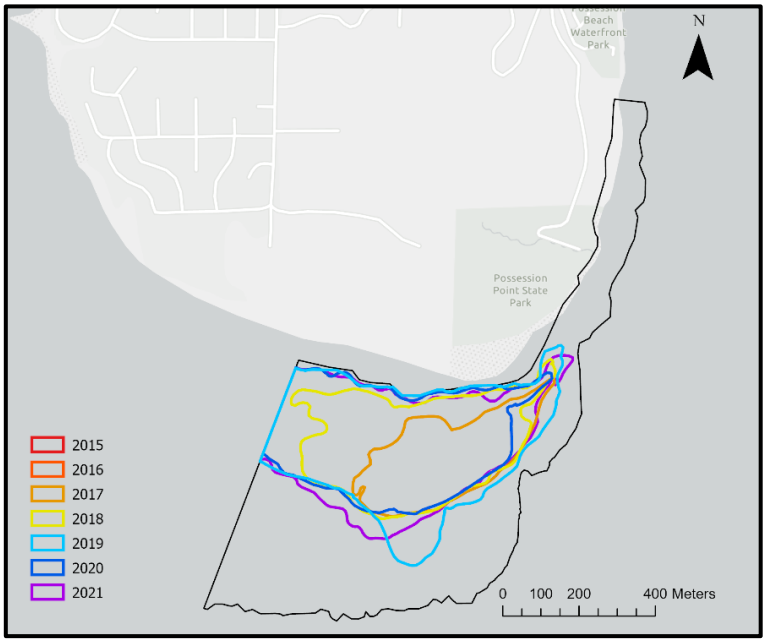
More information:
[Island County MRC]
[NW Straits Commission]



Recent (5 yr) bed trend: **Increasing**

Entire data record: **Increasing**

Island County Marine Resources Committee (MRC) volunteers have monitored Possession Point since 2017. Bed area expanded to the west. Volunteers observed the bed merge with a kelp bed to the west side of the point in 2019. Trend results at this site span a limited number of years, continuing to collect data will enrich our understanding.



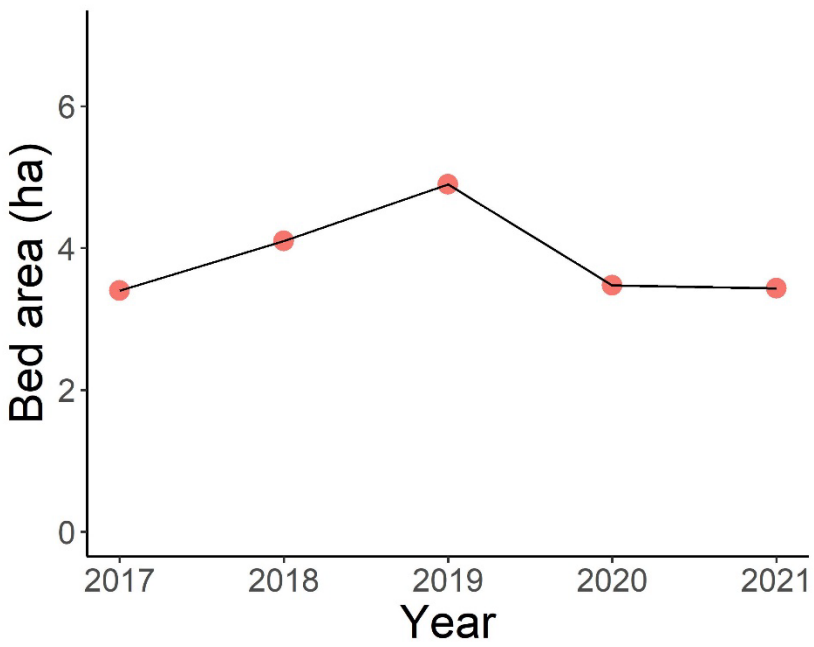
To explore the spatial data visit [Sound IQ]

Photo credit: Julia Ledbetter

Location: Shannon Point – East (SHPT-E)

Sub-basin: North Puget Sound

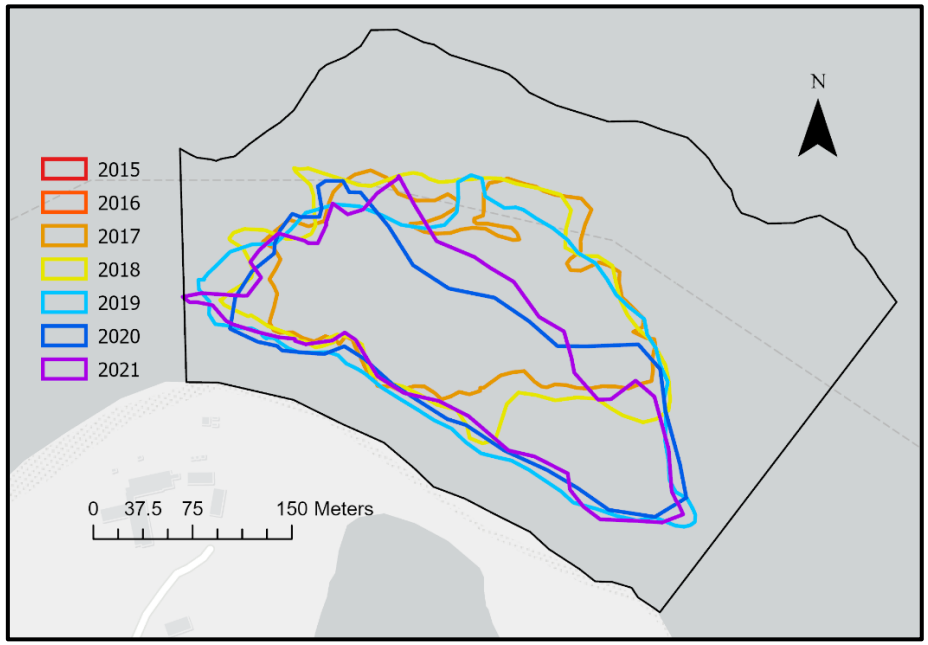
More information:
[Skagit County MRC]
[NW Straits Commission]



Recent (5 yr) bed trend: **No trend**

Entire data record: **No trend**

Skagit County Marine Resources Committee (MRC) volunteers have monitored Shannon Point – East since 2017. The kelp bed is located just west of the Anacortes ferry terminal and can experience strong currents. Bed area has varied slightly but remained stable overall (no significant trend). Trend results at this site span a limited number of years, continuing to collect data will enrich our understanding.



To explore the spatial data visit [Sound IQ]

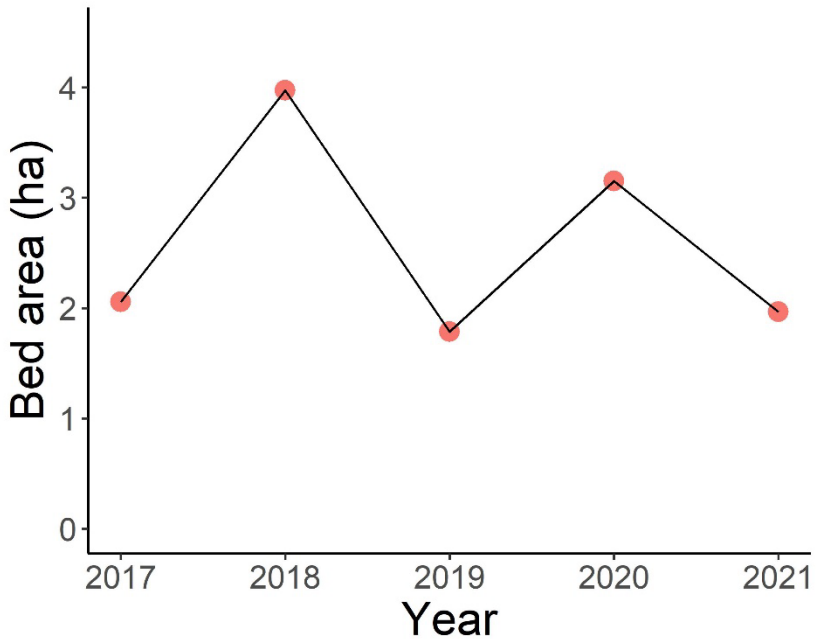

Photo credit: Joan Magee

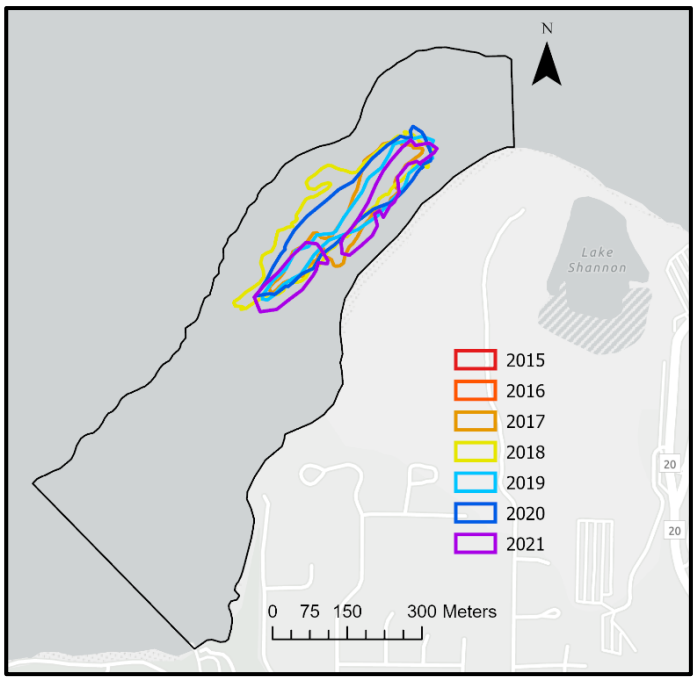
Location: Shannon Point – West (SHPT-W)

Sub-basin: North Puget Sound

More information:
[Skagit County MRC]
[NW Straits Commission]

Kelp Forests WA





To explore the spatial data visit [Sound IQ]

Recent (5 yr) bed trend: **No trend**

Entire data record: **No trend**

Skagit County Marine Resources Committee (MRC) volunteers have monitored Shannon Point – West since 2017. Bed area has been highly variable but remained stable overall (no significant trend). Volunteers have noted that sparse kelp often trails off the west edge of the bed and can influence bed area. Trend results at this site span a limited number of years, continuing to collect data will enrich our understanding.


Photo credit: Lynne Wenberg-Davidson